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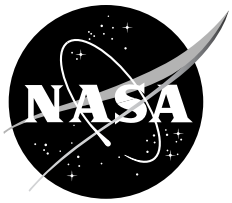

Comanche Helmet-Mounted Display Heading-Tape Simulation: Final Report

Terry Turpin
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Prepared for Ames Research Center
under Contract NAS2-01055

October 2006

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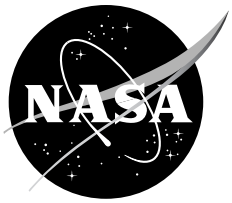

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EXECUTIVE SUMMARY

The Aeroflightdynamics Directorate (AMRDEC) conducted a simulation to assess the performance associated with a Contact Analog, world-referenced heading tape as implemented on the Comanche Helmet Integrated Display Sight System (HIDSS) when compared with a Compressed heading tape similar to that specified by the former Military Standard (MIL-STD) 1295. Six experienced pilots flew three modified Aeronautical Design Standards (ADS)-33 maneuvers (Hover Turn, Bob-up, Transient Turn) and a precision traffic pattern in the NASA Vertical Motion Simulator (VMS). Analysis of the pilot objective performance data and subjective handling qualities ratings (HQRs) showed the following:

Compressed symbology in the Velocity Stabilization (VelStab) flight mode generally produced the most precise performances over Contact Analog symbology with respect to the heading, altitude, position, and time criteria specified for the maneuvers tested. VelStab outperformed the Automatic Flight Control System (AFCS) on all maneuvers achieving desired performance on most maneuvers for both symbol sets. Performance in the AFCS mode was generally desirable to adequate for heading and altitude and did not meet adequate standards for hover position and time for the Hover Turn and Bob-up maneuvers. VelStab and AFCS performance were nearly the same for the Transient Turn. Pilot comments concerning the Contact Analog heading-tape implementation were generally unfavorable in spite of the achieved levels of performance.

HQRs showed Compressed symbology in the VelStab flight mode produced the lowest mean HQR, encompassing mixed ratings of satisfactory handling and needing improvement. All other symbology/flight-mode combinations yielded higher HQRs, which characterized opinions that deficiencies in aircraft handling due to HMD symbology would need improvement. Contact Analog heading tape and other symbology require improvement, especially when operating in the AFCS mode.

NASA-TLX rated Compressed symbology in the VelStab flight mode as the least demanding on resources, closely followed by ratings for Contact Analog in the VelStab mode. In a similar pattern, TLX ratings for maneuvers completed in the AFCS mode yielded a higher level of resource demand with even slighter differences between Contact Analog and Compressed symbology sets.

Further research should be conducted where objective data and subjective HQR ratings indicate a need for improvement. The areas requiring attention are those where the symbology implementation, the flight control system, or a combination of both caused workload to reach an objectionable level where adequate performance was either difficult to achieve or unachievable. These areas are clearly identified in this report. Symbology that received negative HQR comments by a majority of pilots should also be examined. The summary of pilot comments can be found in appendix A. Additional simulation trials should be considered to address the identified issues.

SECTION 1. SIMULATION TEST PLAN

1.1 Simulation Test Objectives

The objective of this simulation was to evaluate the "Contact Analog" implementation of the heading-tape display proposed for the Comanche Helmet-Mounted Display (HMD). This display is intended for use as a primary flight display as defined in MIL-STD-1787C. The test measured pilot performance differences between Comanche Contact Analog symbology and a conventional, Compressed symbology heading-tape display used in the AH-64D Apache HMD (MIL-STD-1295 criteria). This test specifically examined issues voiced by the user community (TRADOC Systems Manager (TSM)-Comanche). The symbology evaluation used performance parameters for selected tasks specified in TC 1-251, Aeronautical Design Standard (ADS)-33, and ADS-46 (draft).

1.1.1 Background

The Comanche RAH-66 Scout/Attack Helicopter will be the first Army helicopter to use a helmet-mounted display as the primary flight display (PFD). The Helmet Integrated Display Sight System (HIDSS) will display flight symbology designed by the prime contractor Sikorsky Aircraft Company. The symbology design concept incorporates an inertially referenced or Earth-referenced system known as "Contact Analog," wherein symbols appear to overlay the real-world objects they represent. Sikorsky has described the Contact Analog design philosophy as maintaining a "Gestalt," where visual, vestibular, and proprioceptive cues remain in agreement. That is, in the virtual world of the HMD, symbols behave like the real-world parameter they represent. "Earth-referenced symbols appear to remain fixed to their referents outside the aircraft. Aircraft-referenced symbols appear to move with the aircraft. Head-referenced symbols appear to move with the head. Decoupling any of these inputs from each other has potential for disorientation. Contact Analog symbology is based on the notion of fidelity to movement, behavior, and interrelationships of real-world referents." Dynamics, location, and behavior of a symbol represent its corresponding source of information in contact (visual) flight.

The HIDSS had not yet been introduced into the Comanche flight test program at the time of this simulation. Initial tests of the primary flight symbology were done by Army pilots in the Sikorsky Engineering Development Simulator (EDS) and in the Comanche Portable Cockpit (CPC) with a surrogate HMD. These tests surfaced issues regarding the usability of certain symbols included in the primary flight symbology set. The issues are related primarily to the implementation of the heading tape, with additional issues related to the implementation of the artificial horizon line. The inability of pilots to confidently perform selected mission tasks with the Contact Analog heading-tape implementation resulted in the release of an Information Paper by the TSM that detailed the heading-tape issues.

The HMD was scheduled for first flight in the summer of 2002. The Army needed to issue a safety-of-flight release to authorize the contractor to proceed with HMD symbology flight testing. Additional test data were needed to support the safety-of-flight decision. The Army requested an independent evaluation of the Contact Analog heading tape to support the safety-of-flight decision.

1.1.2 Simulation Approach

The Aeroflightdynamics Directorate (AFDD) simulation concentrated on the Contact Analog heading-tape implementation. The issues identified by Army pilots were used to test the hypothesis that Contact Analog performed as well as or better than a conventional Compressed heading tape when the HMD was used as a primary flight reference. The simulation attempted to quantify the results with pilot comments and performance measures.

The evaluation pilots were given classroom and simulator training sessions for familiarization with the HMD, the two symbology sets used in the test, the Comanche flight controls, and the Comanche flight control modes. The simulator used was a non-motion-based Vertical Motion Simulator (VMS) cab. The HMD visual image was a virtual Forward Looking Infrared (FLIR) intended to reduce the reliance on the outside scene for flight reference cues. The evaluation of the symbology was intended to have two parts, Constrained Task Execution and Mission Performance. The mission performance task was a realistic tactical reconnaissance mission. Although the task was developed and tested, it was deleted from the task matrix because of simulator availability constraints. Subject pilots flew only the constrained tasks.

Mission-related tasks were designed to force the pilot to rely on the symbology to successfully complete the flight maneuvers. The maneuvers were developed from tasks presented in ADS-46 (draft) and ADS-33, and from TC 1-251 (Aircrew Training Manual for AH-64 Attack Helicopter). They were modified as necessary to ensure reliance on symbology in conjunction with the outside scene. This part of the simulation provided quantitative measures of symbology usability in highly controlled tasks with specified performance requirements. A complete description of the tasks is presented later it this report.

1.1.3 Test Matrix

The test matrix consisted of the constrained tasks for four separate maneuvers. The evaluation pilots were tested in each of the cells of the matrix (a 2 x 4 fully crossed factorial design). The order of presentation was controlled by use of a Latin square. (See table 1.)

TABLE 1. TEST MATRIX

Symbology/Task	Contact Analog	Compressed
a	a-1	a-2
b	b-1	b-2
c	c-1	c-2
d	d-1	d-2

1.2 Simulation Preparation

1.2.1 Control-System Models

The Comanche core Primary Flight Control System (PFCS), mission PFCS, and the Automatic Flight Control System (AFCS) with selectable modes for Hover Hold and Velocity Stabilization (VelStab) were used in the simulation. The models were coded, checked out, and loaded on the VMS host computer. The checkout included both static and dynamic check cases from data supplied

by Boeing. Boeing engineers were on site at Ames for more than a week prior to the simulation. They provided expert assistance to NASA simulation engineers in getting the Comanche math model integrated and running correctly on the Ames VMS computer.

1.2.2 Symbology

The Comanche HMD PFD symbology graphic display and the associated drivers that move the symbology were coded. Other symbology displayed in the actual Comanche such as weapons, systems status, communications, and tactical symbology was not coded for this simulation. The symbology was displayed on a Kaiser ProView 50 HMD supplied by the Comanche Program Manager (PM). The symbology drivers were linked with the Comanche flight math model and control-system models as required for input. Checkout of the symbology and drivers was done during the simulation buildup phase using check cases supplied by Sikorsky.

The Simlab graphics staff developed the PFD compressed symbology display graphics in-house. The display is based on Apache HMD symbology and the former MIL-STD-1295. The symbology was driven using the Comanche drive laws in order to remain compatible with the Comanche control system. The symbology set was checked out in-house by the Comanche simulation team against Boeing design specifications. HMD symbology sets for both Compressed and Contact Analog implementations are shown in figures 1 and 2 respectively.

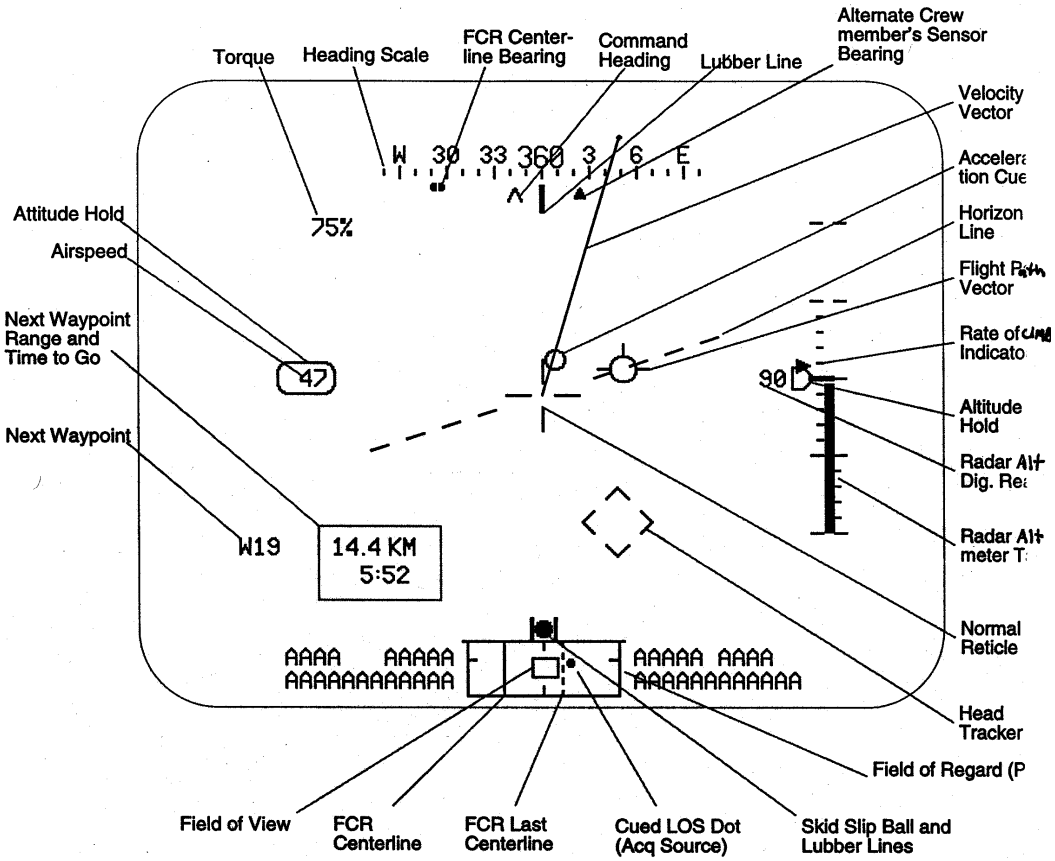

Figure 1. Compressed symbology set.

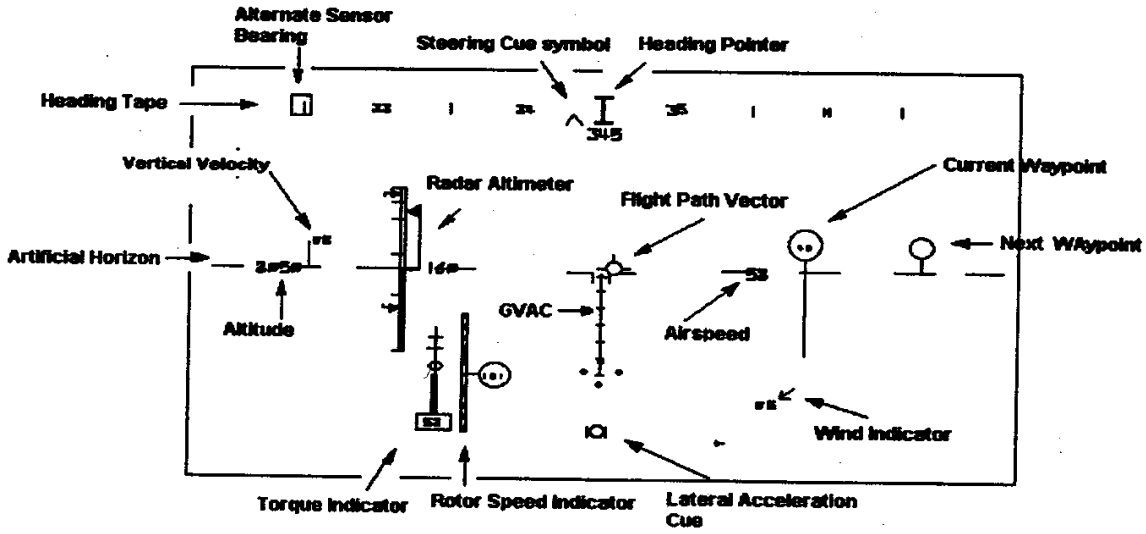

Figure 2. Contact analog symbology set.

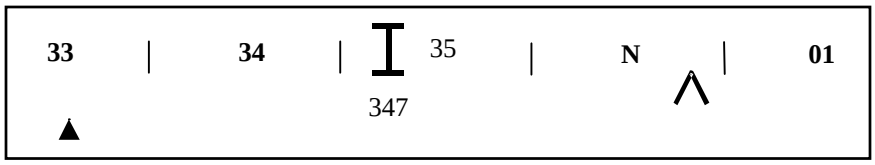

Figure 3. Contact analog heading tape.

1.2.3 Contact Analog Heading-Tape Description

The Contact Analog implementation of the heading tape is illustrated in figure 3. Key features of the symbology are described in bullet form. The paragraphs were taken from the Pilot Vehicle Interface Mechanization Specification (PVIMS) for Comanche (Rev F, 7/99).

- The Comanche HMD heading-tape symbol is Earth stabilized in roll and azimuth and screen stabilized in elevation; it moves across the display in relation to changes in heading of the aircraft and the pilot's head.
- The heading tape remains aligned with the real-world horizon.
- When the aircraft is flying straight and level, the heading tape appears to the pilot as a continuous 360° tape around the aircraft. As an example, if the aircraft is heading due north and the pilot looks 90° to the right, "E" appears at the center of the heading tape.
- The heading tape has numerals at 10° increments (i.e., 10°, 20°, 30°, etc.) and has hash marks at 5° increments in between (i.e., 5°, 15°, 25°, etc.). Alphanumerical characters (N, S, E, W) are displayed at the cardinal headings. The heading tape is removed in the de-clutter mode.
- The heading is referenced to magnetic north.

- The aircraft heading reference appears as an I-Bar that is Earth stabilized in roll, screen stabilized in elevation, and aircraft stabilized in azimuth. The steering cue symbol (upward-pointing caret) is stabilized like the I-Bar symbol and indicates commanded heading (desired heading to next waypoint) and moves horizontally across the display below the heading tape.
- Aircraft heading is displayed digitally in the top center of the HMD display and is screen fixed in that location. The digital readout is boxed when heading hold is engaged.
- The artificial horizon line has occlusion priority over the heading tape when the head is tipped down enough to bring the two symbols into proximity.

1.2.4 Compressed Heading-Tape Description

Figure 4 shows the Compressed implementation of the heading tape.

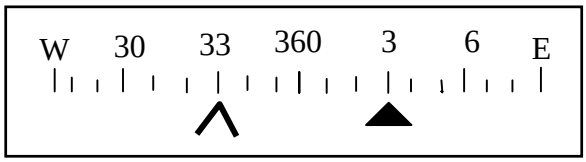

Figure 4. Compressed heading tape.

- Heading tape is screen fixed and displayed at the top area of the HMD. Screen fixed means it appears as if painted on the helmet visor and moves with the pilot's head.
- It is an analog moving scale that presents magnetic heading with a total range of 360°.
- A total of 180° is in the instantaneous field of view at all times.
- The scale is incremented every 10° and the major cardinal headings are alphanumerically labeled.

1.2.5 Simulation CAB

The simulation used the VMS F-CAB as the cockpit; it was set up in the fixed-base lab of the VMS facility. The cockpit was set up for the pilot with only a single seat. The side arm controller (SAC) and collective were installed and adjusted in accordance with specifications provided by Sikorsky. The four-axis SAC was installed on the right side and the collective on the left side. The only panel-mounted display was a single 8- by 8-inch head-down multifunction PFD. Control-system selectable modes were integrated after consultation with the Sikorsky simulation team. The cockpit setup was austere, providing only those controls and displays necessary to conduct the simulation.

1.2.6 Controllers

The pilot crewstation in the F-CAB was configured to emulate the Comanche in terms of functionality of the controllers and controller positions.

A four-axis SAC provided longitudinal and lateral cyclic control, yaw axis control, and limited heave control. This controller was a full emulation of the Comanche SAC. This equipment was borrowed from the Comanche Portable Cockpit to support the experiment. (See fig. 5.)

Figure 5. Comanche 4-axis controller.

An Apache collective was used in the simulation. Although it was not a Comanche collective, the functionality of the controller was matched as closely as possible. Matching included Comanche control forces, length of throw up and down, back-driving the collective, and positioning the trim switch under the grip.

1.2.7 Helmet-Mounted Display

The simulation used a Kaiser ProView 50 HMD as an emulation for the HIDSS, which was still in development at the time of this test. The ProView 50 is an XGA Bi-ocular display (1024 x 780 @ 60 Hz) active-matrix, liquid-crystal display (LCD) with a 30° vertical by 49° horizontal field of view with 25° overlap.

This display has a lower resolution than the proposed Comanche HIDSS system. The HIDSS display will be an all-digital bi-ocular display. It will have active-matrix LCDs, with SXGA resolution (1280 x 1024) and the field of view is 35º x 52º (minimum 17° overlap).

The difference in resolution did not have a large effect on the symbology presentation. The lower contrast of the FLIR sensor scene produced a Level 2 Usable Cue Environment (UCE - 2), resulting in a larger dependence on the symbology versus the outside scene to complete the maneuvers—the desired effect. The symbology images displayed on the HMD were generated by an SGI IRIS computer. The symbology overlaid the FLIR images produced by the ESIG 3000. (See fig. 6.)

1.2.8 Head Tracker

The simulation used a magnetic Polhemus "Fasttrack" Head Tracker. The helmet position sensor was installed above the pilot’s head and to the rear of the F-CAB. The transmitter was installed on the top of the HMD. A thorough mapping of the head tracker envelope and an HMD-to-visual scene calibration was completed during the simulation setup.

Figure 6. Helmet mounted display.

1.2.9 Image Generator for HMD

The FLIR visual display for the HMD was generated by an Evans and Sutherland Image Generator (computer-generated image (CGI)), (model ESIG 3000). The terrain database used for the simulation is called the ANOE database. Figure 7 shows a map of the database. The evaluations with FLIR forced pilots to rely more heavily on the symbology and presented a UCE 2 visual image.

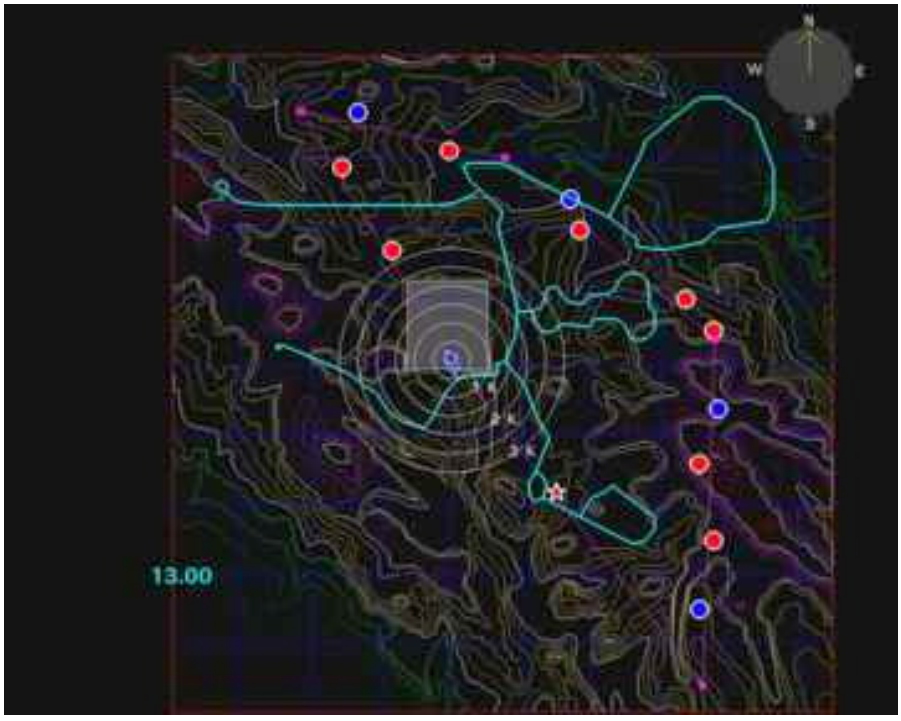

Figure 7. Plan-view map of ANOE CGI database.

1.3 Simulation CAB Checkout

1.3.1 Math Model and Controller Checkout

The mathematical models for the control system were checked out using check cases supplied by Boeing. As previously mentioned, the checkout included onsite help from a Boeing Flight Controls engineer.

The math model for the symbology drivers was checked out by the Simlab graphics engineer and was checked out further with the assistance of a Sikorsky human factors engineer during the shakedown phase.

The controllers were set up according to the Sikorsky math model values and checked with force gages. Plots of the controller characteristics were made for documentation.

The AFDD project pilot then checked out the combination of math model and controllers by flying several tasks from a pretest matrix. This served to set up the tasks and to check out the performance standards.

When the cab was set up and checked locally, Sikorsky's chief test pilot for the Comanche program visited Ames and flew the simulator. He flew specific maneuvers and measured the results against the design specification for the actual aircraft. He also offered subjective comments concerning the handling qualities of the simulator. Deficiencies were noted and corrected during an intense validation test that lasted four days. A similar validation was conducted by a visiting human factors engineer, who examined the design and functionality of each symbol compared to the design specification. Again, noted deficiencies were corrected immediately.

1.4 Simulation Execution

1.4.1 Test Subject Training and Performance Runs

The simulation was performed over a period of five weeks. Groups of two pilots each were scheduled throughout the test period. Each group of pilots spent five days completing training and the test requirements. The training sessions involved a half day of ground school where the pilots were given an overview of the functionality of each symbol in both symbol sets, an explanation of the flight controls and flight control modes, and an overview of the flight-test maneuvers and standards. They were then given two structured familiarization flights in the simulator where they experienced all control modes using both symbology sets. When training was completed and the pilots were comfortable with the controls and displays, they were required to fly an evaluation task to a predetermined performance standard before being allowed to proceed to the flight-test phase.

During the flight-test and data-collection phase, each pilot flew a series of four specific maneuvers using one symbology set (Contact Analog or Compressed), and then flew the same maneuvers using the other symbology set. Four practice runs and four data runs were flown for each of the four maneuvers. Each maneuver (except the traffic pattern) was flown in both directions, left and right.

1.4.2 Data Collection
Several different data-collection methods were used to support the simulation, as detailed in the following paragraphs.

1.4.3 Task Performance
Task-performance measures were recorded using computational techniques developed by the Simlab. These measures were captured by the Show Print summary after each maneuver was performed. This provided immediate postrun summary and feedback to the pilot following each maneuver.

1.4.4 HQR
Cooper/Harper HQRs were taken following the completion of a four-data-run set for a given flight control system, symbology set, and maneuver. Figure 8 on page 12 shows a copy of the Cooper/Harper HQR rating scale.

1.4.5 NASA-TLX
NASA-TLX workload-rating-scale data were collected immediately following each maneuver dataset. The scale was filled out based on a subjective assessment made by the pilot concerning mental, physical, and temporal demand. It also captured data concerning how the pilot felt about his performance of the task, the level of effort put into the task, and the level of frustration experienced in completing the maneuver.

1.4.6 X-Y Plotter
An X-Y plotter (electronic form) showed aircraft vertical and horizontal position during the maneuvers.

1.4.7 RUNDUM Dataset
RUNDUM data were collected each second, recording the variables specified for each task such as time, position, altitude, heading, and a myriad of others.

1.4.8 Data Analysis
The collected datasets were summarized in tables, graphs, and narrative comments from the subject test pilots. The format chosen depended on the nature of the data.

1.4.9 Subject Pilot Evaluators
Six male pilots supported the simulation. Four were experimental test pilots from the U.S. Army Aviation Technical Test Center, Ft. Rucker, Alabama, and two were Army/NASA test pilots. All six were instrument rated. Their ages ranged from 33 to 55 (Mean (M) = 41.33 years). Five pilots had previous experience with an HMD in a simulator and in an aircraft (Median (Mdn) = 57.5 hr, Mdn = 115 hr, respectively). Reported time spent in a simulator ranged from 100 to 1300 hr (Mdn = 425 hr). All six pilots had experience with night-vision goggles (Mdn = 250 hr). Total flight hours in a helicopter ranged from 1500 to 6700 hr (Mdn = 2850 hr). Additionally, fixed-wing flight hours ranging from 200 to 2500 hr (Mdn = 200 hr) were reported by five pilots.

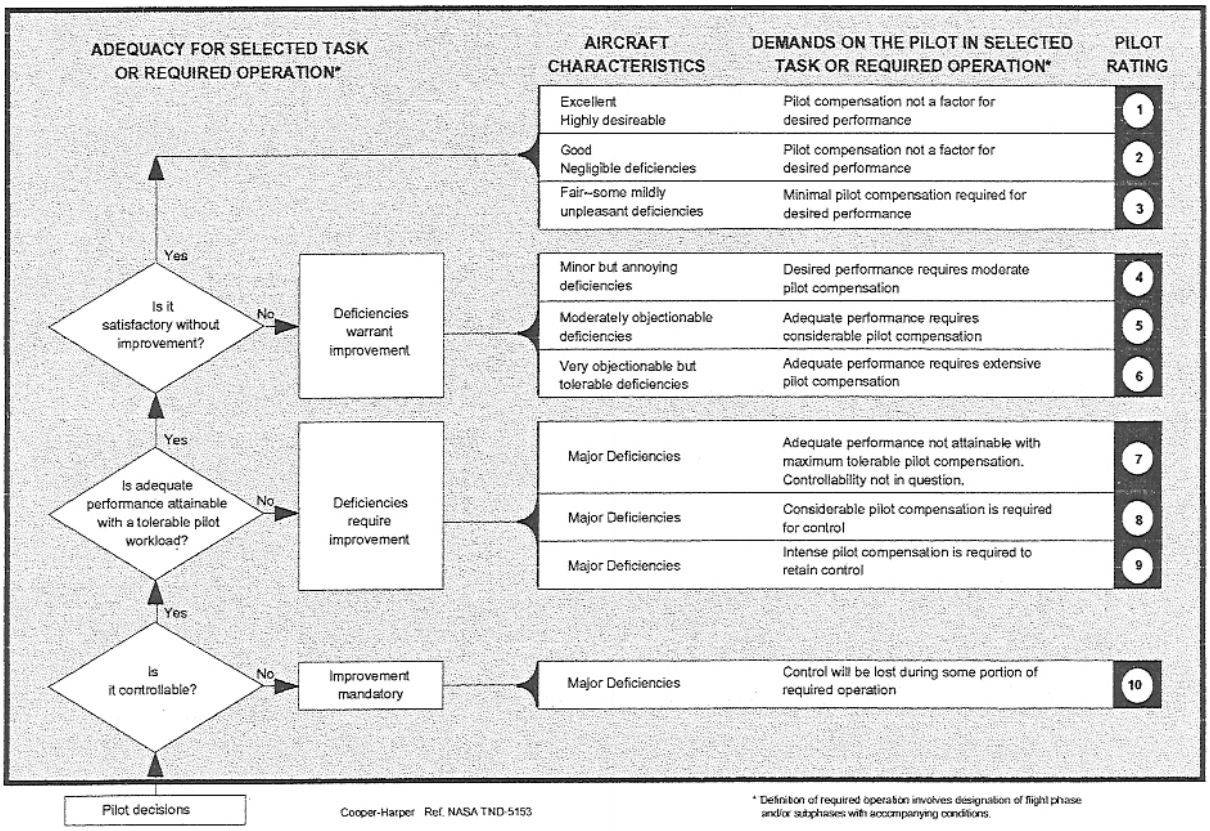

Figure 8. Cooper/Harper Handling Qualities Rating (HQR) scale.

HQR 1. Excellent – Highly desirable. Pilot compensation not a factor for desired performance.

HQR 2. Good – Negligible deficiencies. Pilot compensation not a factor for desired performance.

HQR 3. Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.

HQR 4. Minor deficiencies. Desired performance required considerable pilot compensation.

HQR 5. Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.

HQR 6. Very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation.

HQR 7. Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.

HQR 8. Major deficiencies. Considerable pilot compensation is required for control.

HQR 9. Major deficiencies. Intense pilot compensation is required to retain control.

HQR 10. Major deficiencies. Control will be lost during some portion of required operation.

SECTION 2. EVALUATION FLIGHT TASK MANEUVERS

2.1 Heading Tape Test and Evaluation Flight Tasks

The following flight tasks were intended to be mission-related tasks that would be performed by Army pilots in a scout/attack helicopter such as the Comanche. These tasks and performance standards were validated during the checkout phase of the simulation setup by the project test pilots. An unusual attitude task and a comprehensive combat mission task were developed, tested, and included in the original task matrix to address user concerns. However, these two tasks were deleted from the formal test because of simulator availability and other resource constraints.

The four maneuvers described were developed from selected handling qualities tasks specified in ADS-33, ADS-46 (draft), and TC 1-251. The tasks selected were those that required use of the heading tape as the primary reference to successfully complete the maneuver. Some task modifications were required to make the heading tape a more prominent feature in executing the maneuver. Pilot-performance measures were developed using the references mentioned previously. Detailed task descriptions follow.

2.1.1 Task 1. Turn-to-Target (Hover Turn)

The turn-to-target is an appropriate task for examining the effectiveness of the heading tape during a rapid hovering turn while pointing the aircraft toward an off-axis target.

a. Reference: ADS-46 (draft), June 1998, Par. 7.9.1; ADS-33, May 1996, Par. 4.2; TC 1-251, ATM Task 1107, Hovering Flight.

b. Objectives: This test checks the pilot's ability to use the display symbology to recover from a rapid hovering turn with sufficient precision to fire a weapon. This is an aircraft pointing exercise. No weapons will be fired.

c. Requirements: This evaluation can be flown using any convenient aiming point located approximately 180° to the initial aircraft heading or to a precise heading (test used precise heading).

d. Maneuver: From a stabilized hover at an altitude of not less than 20 ft, complete a rapid 180° hovering turn-to line up with a known target. If a target is not available, an exact "turn-to" heading may be specified by the test controller (used exact headings). Turns will be completed in both directions.

e. Data: The following aircraft performance data were recorded:

- Time required to turn
- Radar altitude
- Aircraft position
- Heading angle and tracking accuracy

f. Performance criteria:

Desired performance:

- Maintain longitudinal and lateral position of a selected point on the aircraft within 6 ft of a selected point on the ground.
- Maintain altitude within ±3 ft.
- Stabilize final aircraft heading within ±5°.
- Complete the turn so that a firing solution has been achieved within 15 seconds from the initiation of the maneuver.

Adequate performance:

- Maintain longitudinal and lateral position of a selected point on the aircraft within 12 ft of a selected point on the ground.
- Maintain altitude within ±6 ft.
- Stabilize final aircraft heading within ±10°.
- Complete the turn so that a firing solution has been achieved within 15 seconds from the initiation of the maneuver.

2.1.2 Task 2. Turn-to-Target Bob-up

This test repeats the turn-to-target test except that the pilot's head must be turned first to place his line of sight (LOS) on the target prior to turning the aircraft to point at the target, i.e., turn the pilot's head, and then align the aircraft. In addition, simultaneous with the turn, the pilot will execute a Bob-up maneuver to a 50-ft out-of-ground-effect (OGE) hover. The turn will be limited to approximately 90° because of head-turning limitations.

a. Reference: ADS-46 (draft), June 1998, Par. 7.9.1, and 7.9.3. ADS-33, May 1996, Par. 4.2, and 4.2.2; TC 1-251, ATM Task 1107, Hovering Flight, and Task 1151, Masking and Unmasking.

b. Objectives: This maneuver checks the pilot's ability to use the display symbology to control a rapid hovering turn coupled with a rapid Bob-up maneuver with sufficient precision to fire a weapon after completion of the climbing turn. This simulates rising vertically from a masked firing position while quickly turning to engage a known enemy position 90° off axis.

c. Requirements: This maneuver will begin on a cardinal heading at approximately 10-ft above ground level (AGL). The pilot will turn 90° while simultaneously climbing to 60-ft AGL.

d. Maneuver: This maneuver represents the combining of two different maneuvers specified in the references cited previously. Those maneuvers are the turn-to-target and the hover Bob-up. From a stabilized hover at an altitude of approximately 10 ft, the pilot will acquire a target approximately 90° left or right of the longitudinal axis of the aircraft. While keeping the HMD sighting reticle aligned with the target, the pilot will complete a 90° hovering turn while simultaneously climbing to an OGE hover altitude of 60 ft. The objective will be to arrive at 60-ft AGL at approximately the same time target alignment is achieved. Turns shall be completed in both directions to a specified heading.

e. Data: The following aircraft performance data should be recorded:

- Time required to turn
- Radar altitude
- Aircraft position
- Heading angle and pointing accuracy

f. Performance criteria:

Desired performance:

- Maintain longitudinal and lateral position of a selected point on the aircraft within 6 ft of a selected point on the ground.
- Climb to and maintain 50-ft AGL ±5 ft.
- Stabilize final aircraft heading ±4° of the target.
- Complete the turn so that a firing solution has been achieved within 15 seconds from the initiation of the maneuver.

Adequate performance:

- Maintain longitudinal and lateral position of a selected point on the aircraft within 10 ft of a selected point on the ground.
- Climb to and maintain 50-ft AGL ±10 ft.
- Stabilize final aircraft heading ±6° of the target.
- Complete the turn so that a firing solution has been achieved within 20 seconds from the initiation of the maneuver.

2.1.3 Task 3. Transient Turn

This maneuver involves a steep turn initiated from a stabilized en-route altitude and airspeed, rolling out momentarily every 45°. The consecutive turns will continue through a full 180°. The maneuver will be initiated with the pilot looking 45° off axis in the direction of the turn.

a. Reference: ADS-46 (draft), June 1998, Par. 7.9.8; ADS-33, May 1996, Par. 4.2.8, TC 1-251, ATM Task 1117, VMC Flight Maneuvers.

b. Objectives: The objectives include checking the display symbology adequacy in allowing the pilot to initiate, control, and recover from a moderately steep, up-and-away turn while maintaining a constant bank angle and altitude. An additional objective is to roll out wings level precisely at the specified 45° headings. The rollout portion of this maneuver is a deviation from the maneuver specified in the references and is intended to increase dependence on the heading tape during a high workload maneuver.

c. Requirements: The aircraft will begin the maneuver at an altitude that will ensure obstacle clearance, heading 360°. Initial airspeed will be 120 knots indicated airspeed (IAS).

d. Maneuver: The pilot will turn his head 45° in the direction of the turn (right or left), and then execute a relatively steep 30° to 45° angle of bank turn and hold it until the aircraft approaches 45° of turn. Anticipating that point, the pilot will roll wings level in sufficient time to prevent

dynamic overshoot of the rollout heading. The head may be returned forward during the rollout sequence. When the aircraft is stabilized with wings level on the appropriate heading mark, the maneuver will be repeated every 45° until a full 180° turn has been completed. A total of three interim stops will be made. The maneuver will be repeated in the opposite direction.

e. Data: The following aircraft performance data should be recorded:

- Constant altitude
- Stable pitch and bank angles required to maintain a 30° to 45° angle of bank
- Rollout heading accuracy
- Proper off-axis head position

f. Performance criteria:

Desired performance:

- Maintain altitude in the turn ±50 ft.
- Rollout on assigned heading ±2° with minimal over/undershoot.
- Stabilize the aircraft after rollout within 12 sec.
- Maintain spatial orientation.

Adequate performance:

- Maintain altitude in the turn ±100 ft.
- Roll out on assigned heading ±5° with minimal over/undershoot.
- Stabilize the aircraft after rollout within 15 sec.
- Maintain spatial orientation.

2.1.4 Task 4. Traffic Pattern

The traffic pattern is an appropriate task for examining the effectiveness of the heading tape during a maneuver requiring multiple turns while climbing and descending. It requires the use of nearly every symbol used for primary flight reference.

a. Reference: TC 1-251, ATM Task, Traffic Pattern.

b. Objectives: This maneuver checks the pilot's ability to use the display symbology to roll out on precise headings while managing the workload of maintaining exact altitudes, airspeeds, and rates of climb and descent.

c. Requirements: This evaluation can be flown using any convenient departure and landing point.

d. Maneuver: From a hover, execute a normal climb straight ahead. At 80 kts execute a climbing 90° (L/R) turn to roll out on a crosswind leg at a climb rate of approximately 500 feet per minute (fpm). At an appropriate point, turn 90° (L/R) to the downwind leg and continue climb to 1500-ft mean sea level (MSL) and level the aircraft. Continue level flight at 1500 ft and 80 kts until arriving at an appropriate position to turn base leg. Turn 90° (L/R) to base leg while maintaining 1500-ft MSL and 80 kts. At an appropriate position, turn to approximately 90° (L/R) to align the aircraft with the intended landing spot while maintaining 80 kts. At a point in space where a

steep approach (≥12°) can be made to the original point of departure, execute a descending and decelerating steep approach to arrive over the original point of departure at a 10-ft hover (0 forward speed).

e. Data: The following aircraft performance data should be recorded:

- Airspeed
- MSL altitude
- Rate of climb
- Headings
- Angle of descent

f. Performance criteria:

Desired performance:

- Maintain altitude ±100 ft.
- Maintain airspeed ±10 kts.
- Maintain specified headings ±10°.
- Maintain rate of climb ±100 fpm.

Adequate performance:

- Maintain altitude ±100 ft.
- Maintain airspeed ±10 kts.
- Maintain specified headings ±10°.
- Maintain rate of climb ±100 fpm.

2.2 Comanche Flight Control Modes

The flight tasks were performed using two different flight control modes. In order to understand the test results, we must understand what these modes do and do not do concerning aircraft stabilization. The following paragraphs present a simplified overview of the features of the Velocity Stabilization (VelStab) mode and the Automatic Flight Control System (AFCS) mode.

The simulation was flown using two different flight control modes: The Core AFCS only and the AFCS with selectable modes VelStab and Altitude Hold engaged.

The Core AFCS features Rate Command/Attitude Hold in pitch and roll, Heading Hold in the yaw axis, and Turn Coordination above 60 knots airspeed.

The VelStab mode features Attitude Command/VelStab in the pitch axis and the roll axis has Rate Command/Attitude Hold for low speeds and Attitude Command/Attitude Hold at high speeds (>80 knots). Heading Hold and turn coordination are extended to low speeds (referenced to ground speed). The VelStab system is useful at hover/low-speed operation and provides Velocity

Command/Position Hold below 5 knots ground speed. Within 3 knots ground speed the system captures Hover/Position Hold and automatically engages Altitude Hold. Altitude Hold is otherwise selectable in either Core AFCS mode or the VelStab mode (on or off).

From an operational perspective, AFCS without selectable modes engaged is more of a "hand-flying" mode used for aggressive maneuvering such as nap-of-the-Earth flight. VelStab/Altitude Hold mode is used when heavily augmented (autopilot) type control is required such as in degraded visual environments and low-speed hovering flight where additional stabilization is needed.

2.3 Environmental Conditions

Table 2 gives the simulated visual conditions.

TABLE 2. SIMULATED VISUAL CONDITIONS

Environmental conditions evaluation task	Simulated visual conditions	Day/night	Visibility, miles	Ceiling, ft
1 through 4	Visual flight rules FLIR image	Night	3	>1000

SECTION 3. SIMULATION TEST RESULTS

3.1 Simulation Test Results Overview

This section presents objective and subjective simulation test results. Analysis includes comparisons between flight control modes and between symbology sets with respect to pilot performance in meeting the standards prescribed for each flight task. A summary of the HQRs is also presented. The statistical-analysis information presented shows average performance. A more detailed performance analysis is presented following the objective analysis. This section shows the detailed, selected individual performance charts, and pilot comments following the maneuver as pilots justify their HQR and TLX ratings. In some cases, the detailed analysis points out more significant differences in performance than may be indicated by the statistical analysis. Both sections should be read in order to get the complete picture of what occurred during this simulation.

3.2 Objective Test Results

Five of the six pilots completed four evaluative maneuvers (Hover Turn, Hover Bob-up, Transient Turn, and Traffic Pattern) in both Contact Analog and Compressed symbology sets. One pilot completed three evaluative maneuvers (Hover Turn, Hover Bob-up, Traffic Pattern) in both symbology sets. Statistical results are presented for maneuvers that yielded immediate data output (Hover Turn, Hover Bob-up, Transient Turn). Data analyzed across maneuvers represent the performance of six pilots for Hover Turn and Hover Bob-up, and five pilots for the Transient Turn.

3.3 Hover Turn Maneuver

Separate 2 x 2 x 4 within-subjects repeated measures analysis of variance (ANOVAs) (Symbology x Flight Mode x Replication) were conducted on longitudinal remote manipulator system (RMS), lateral RMS, altitude, heading, and time performance data. Planned comparisons were examined on symbology and flight mode variables as related to each subset of performance data independently.

3.3.1 Longitudinal Performance

A main effect of flight mode was found, F (1, 5) = 76.05, $p < 0.001$, such that AFCS flight mode (M = 27.14 ft) yielded significantly greater longitudinal deviation than VelStab flight mode (M = 3.39 ft) (fig. 9). The performance standards for the maneuver specified maintaining hover position ±6 ft for desired and ±12 ft for adequate performance. No significant interaction of symbology and flight mode was found. No other significant effects were found.

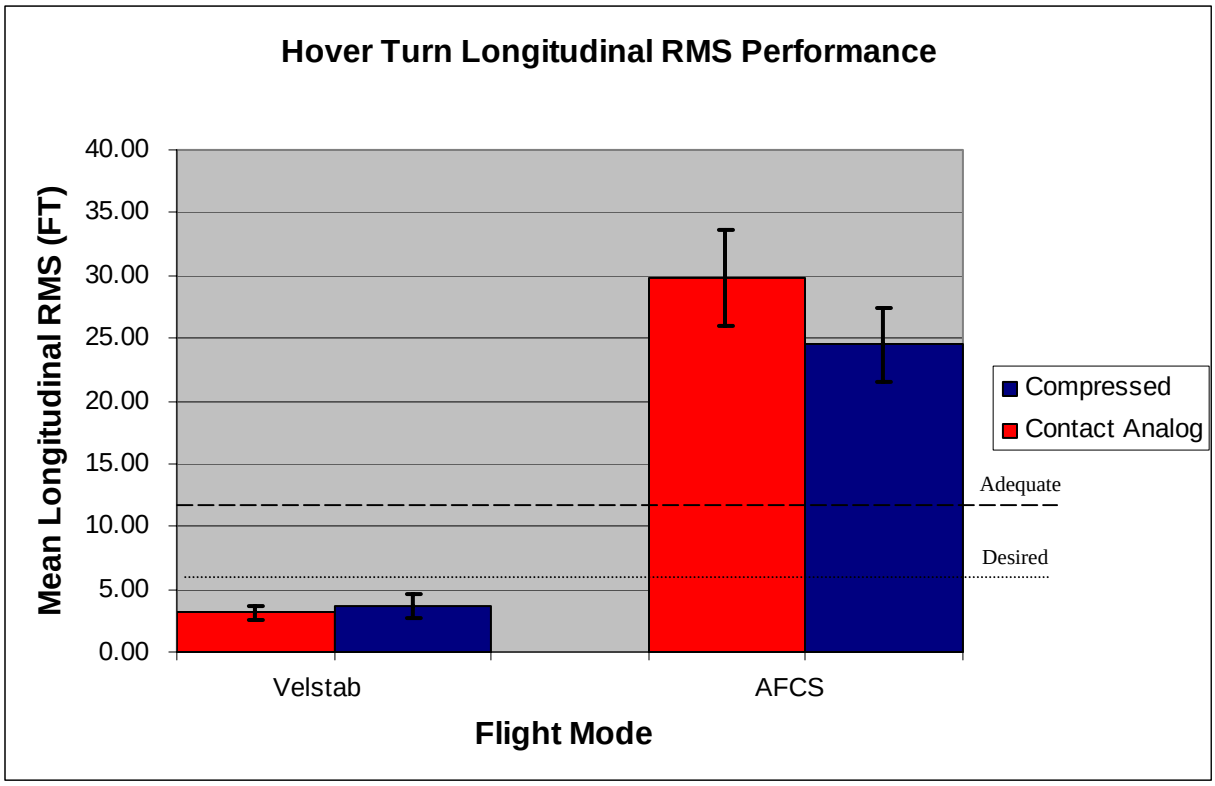

Figure 9. Effect of flight mode on Hover Turn longitudinal RMS performance.

In summary, Hover Turn maneuvers executed in VelStab flight mode, while using Compressed (M = 3.64 ft) or Contact Analog symbology (M = 3.14 ft), yielded longitudinal RMS performances within desired range. However, maneuvers performed in AFCS flight mode in either Compressed (M = 24.50 ft) or Contact Analog symbology (M = 29.77 ft) yielded inadequate performances for the longitudinal RMS parameters given. Overall, mean longitudinal RMS was greatest when the Hover Turn was executed in AFCS flight mode using Contact Analog symbology.

3.3.2 Lateral Performance

A main effect of flight mode was found, F (1, 5) = 40.81, $p < 0.01$, such that AFCS flight mode (M = 25.44 ft) yielded significantly greater lateral deviation than VelStab flight mode (M = 3.78 ft) (fig. 10). The performance standards for the maneuver specified maintaining hover position ±6 ft for desired and ±12 ft for adequate performance. No significant interaction of symbology and flight mode was found. No other significant effects were found.

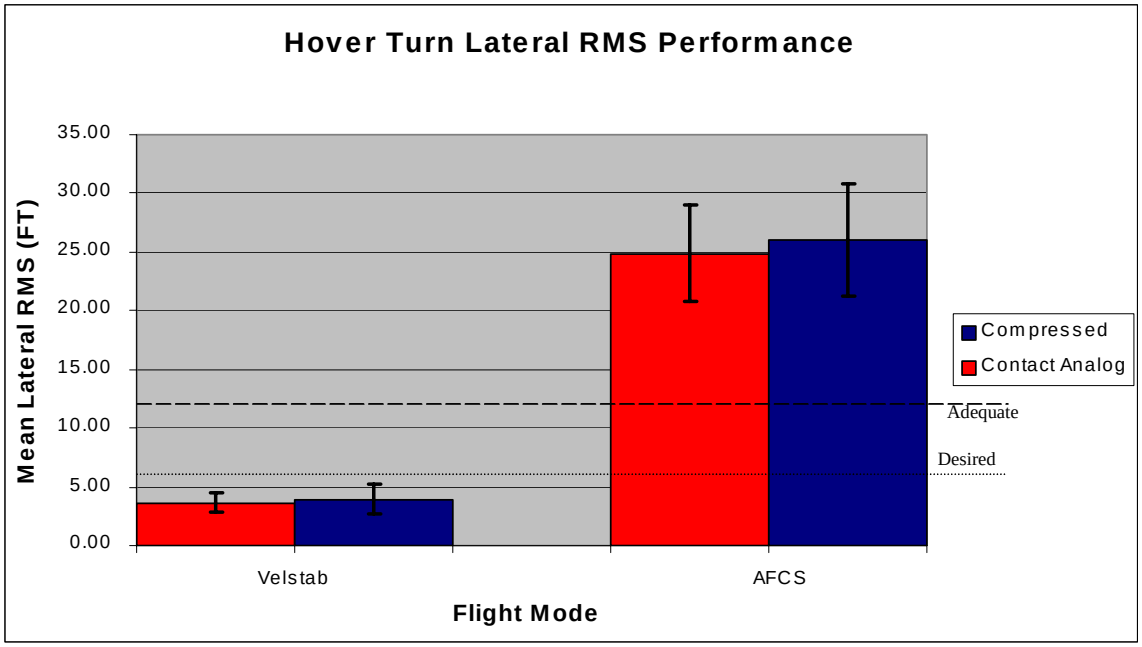

Figure 10. Effect of flight mode on Hover Turn lateral RMS performance.

To summarize, Hover Turn maneuvers executed in VelStab flight mode, while using Compressed (M = 3.92 ft) or Contact Analog symbology (M = 3.64 ft), yielded lateral RMS performances within desired range. However, maneuvers performed in AFCS flight mode in either Compressed (M = 26.01 ft) or Contact Analog symbology (M = 24.86 ft) yielded inadequate performances for the lateral RMS parameters given. Overall, mean lateral RMS was greatest when the Hover Turn was executed in AFCS flight mode using Compressed symbology.

3.3.3 Altitude Performance

A main effect of flight mode was found, F (1, 5) = 64.05, $p < 0.001$ such that AFCS flight mode (M = 4.69 ft) yielded significantly greater final altitude deviation than VelStab flight mode (M = 0.52 ft) (fig. 11). Additionally, a marginal main effect of symbology was found, F (1, 5) = 5.36, p = 0.07 such that Contact Analog symbology (M = 3.07 ft) yielded significantly greater final altitude deltas than Compressed symbology (M = 2.13 ft). The performance standards for the maneuver specified maintaining a constant altitude of ±3 ft for desired and ±6 ft for adequate performance. No significant interaction of symbology and flight mode was found. No other significant effects were found. There are several potential causes for the difficulty in controlling altitude in AFCS. One may be that all of the pilot's attention was required to manage heading, leaving little time to cross check the altitude. Wrist coupling may have also played a part during the rapid cyclic twist to execute the turn. A third possible cause was that the tail rotor caused a lifting effect when attempting to stop the rapid turn. Much of the altitude gain was noted while the turn rate was being arrested. None of these theories has been validated.

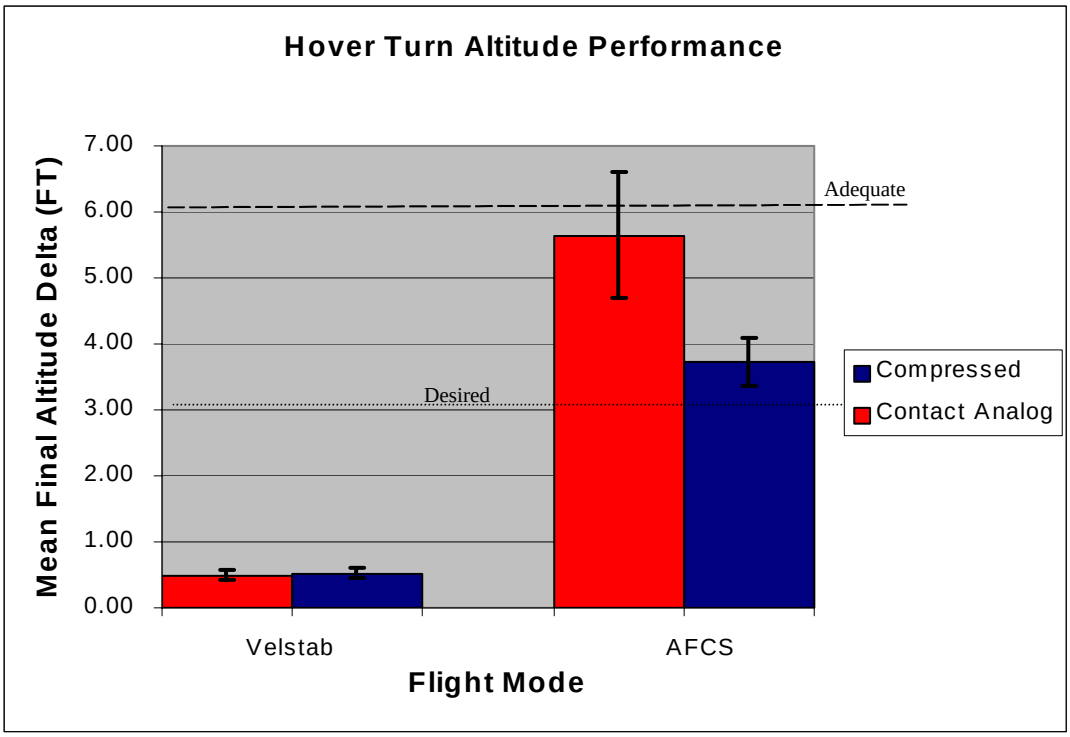

Figure 11. Effect of flight mode on Hover Turn altitude performance.

In summary, Hover Turn maneuvers executed in VelStab flight mode, while using Compressed (*M* = 0.53 ft) or Contact Analog symbology (*M* = 0.50 ft), yielded final altitude heading deltas within desired range. Maneuvers performed in AFCS flight mode in Compressed symbology (*M* = 3.73 ft) and Contact Analog symbology (*M* = 5.64 ft) yielded adequate performances for the final altitude delta parameters given. It should be noted that performance in Hover Turn maneuvers executed in Contact Analog AFCS mode (*M* = 5.64 ft) would have been within inadequate performance range if a 6-ft mean deviation existed.

3.3.4 Heading Performance

No significant interaction of symbology and flight mode was found (fig. 12). No other significant effects were found.

In summary, mean heading deviation for Hover Turn maneuvers across all experimental conditions were recorded with means below ±5° deviation. The performance standards for the maneuver specified maintaining rolling out on a specified heading ±5° for desired and ±10° for adequate performance. Therefore, heading deviation data across all conditions were deemed desired performances.

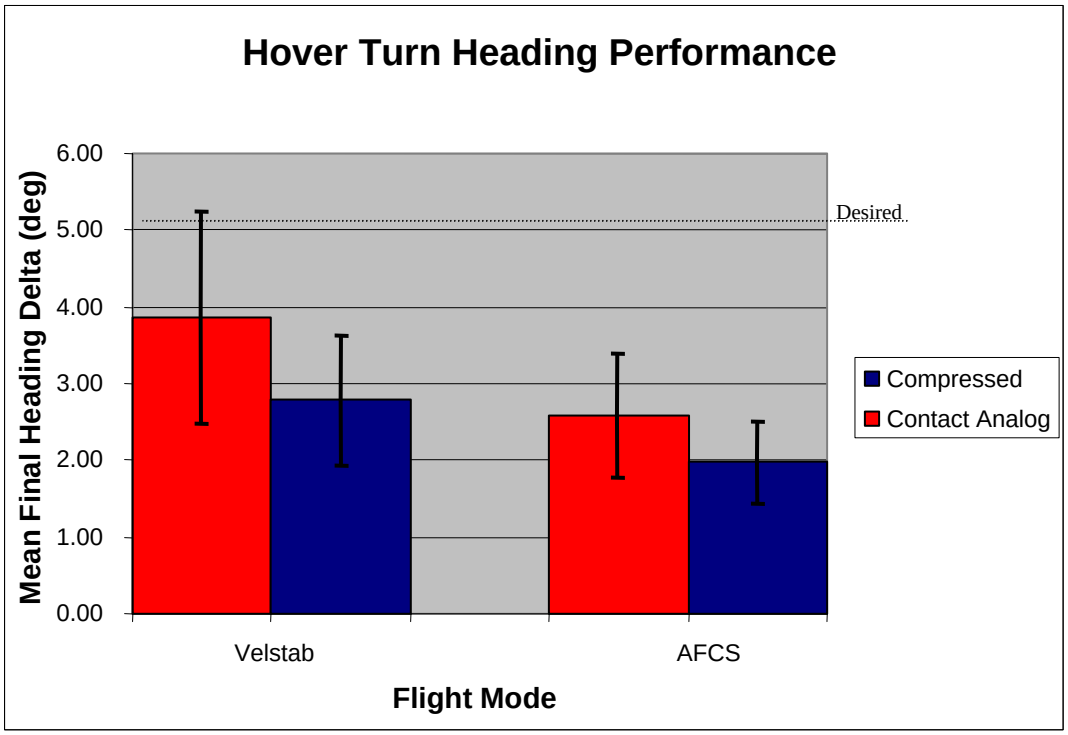

Figure 12. Effect of flight mode on Hover Turn heading performance.

3.3.5 Time Performance

A main effect of flight mode was found, F (1, 5) = 13.42, $p < 0.05$, such that AFCS flight mode (M = 19.08 sec) yielded significantly longer times to stabilize than VelStab flight mode (M = 11.33 sec) (fig. 13). The performance standards for the maneuver specified rolling out on a specified heading within 15 seconds for desired and for adequate performance. No significant interaction of symbology and flight mode was found. No other significant effects were found.

In summary, Hover Turn maneuvers executed in VelStab flight mode, while using Compressed (M = 11.96 sec) or Contact Analog symbology (M = 10.69 sec), yielded mean times to stabilize within desired range. However, maneuvers performed in AFCS flight mode in both Compressed symbology (M = 18.63 sec) and Contact Analog symbology (M = 19.52 sec) yielded inadequate performances for the time to stabilize parameters given.

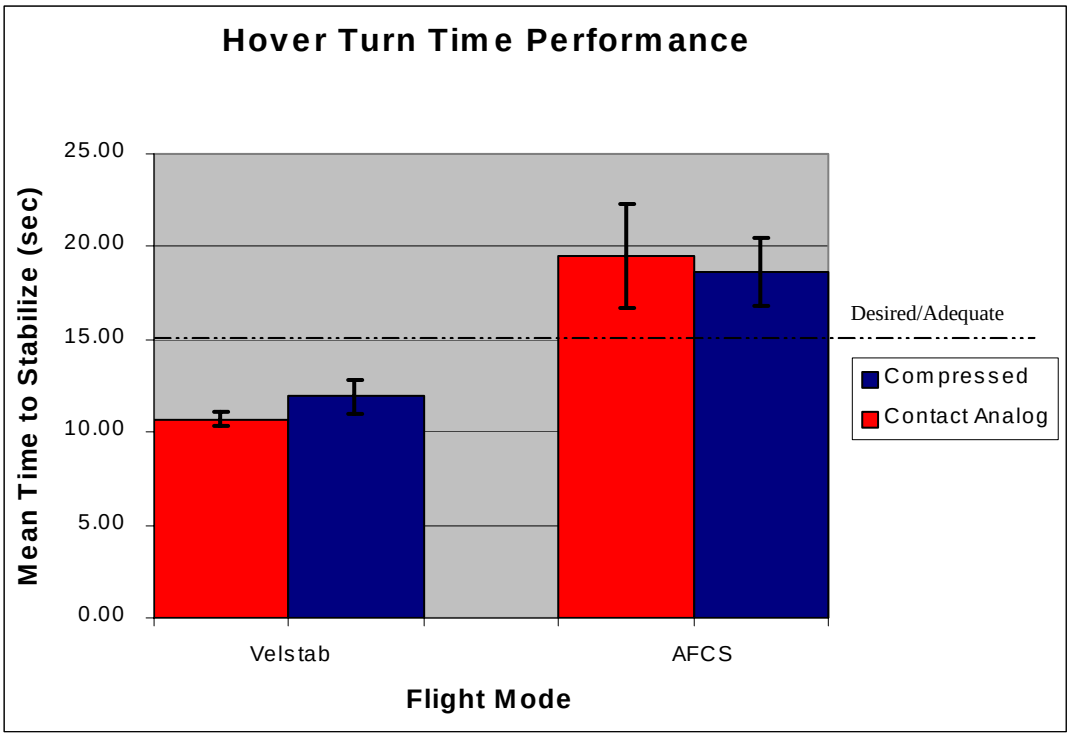

Figure 13. Effect of flight mode on Hover Turn time performance.

3.4 Hover Bob-up Maneuver

Separate 2 x 2 x 4 within-subjects repeated measures ANOVAs (Symbology x Flight Mode x Replication) were conducted on longitudinal RMS, lateral RMS, altitude, heading, and time performance data. Planned comparisons were examined on symbology and flight-mode variables as related to each subset of performance data independently.

3.4.1 Longitudinal Performance

A main effect of flight mode was found, F (1, 5) = 24.75, $p < 0.01$, such that AFCS flight mode (M = 19.25 ft) yielded significantly greater longitudinal deviation than VelStab flight mode (M = 6.98 ft) (fig. 14).

The performance standard called for maintaining longitudinal position ±6 ft for desired and ±10 ft for adequate performance. No significant interaction of symbology and flight mode was found. No other significant effects were found.

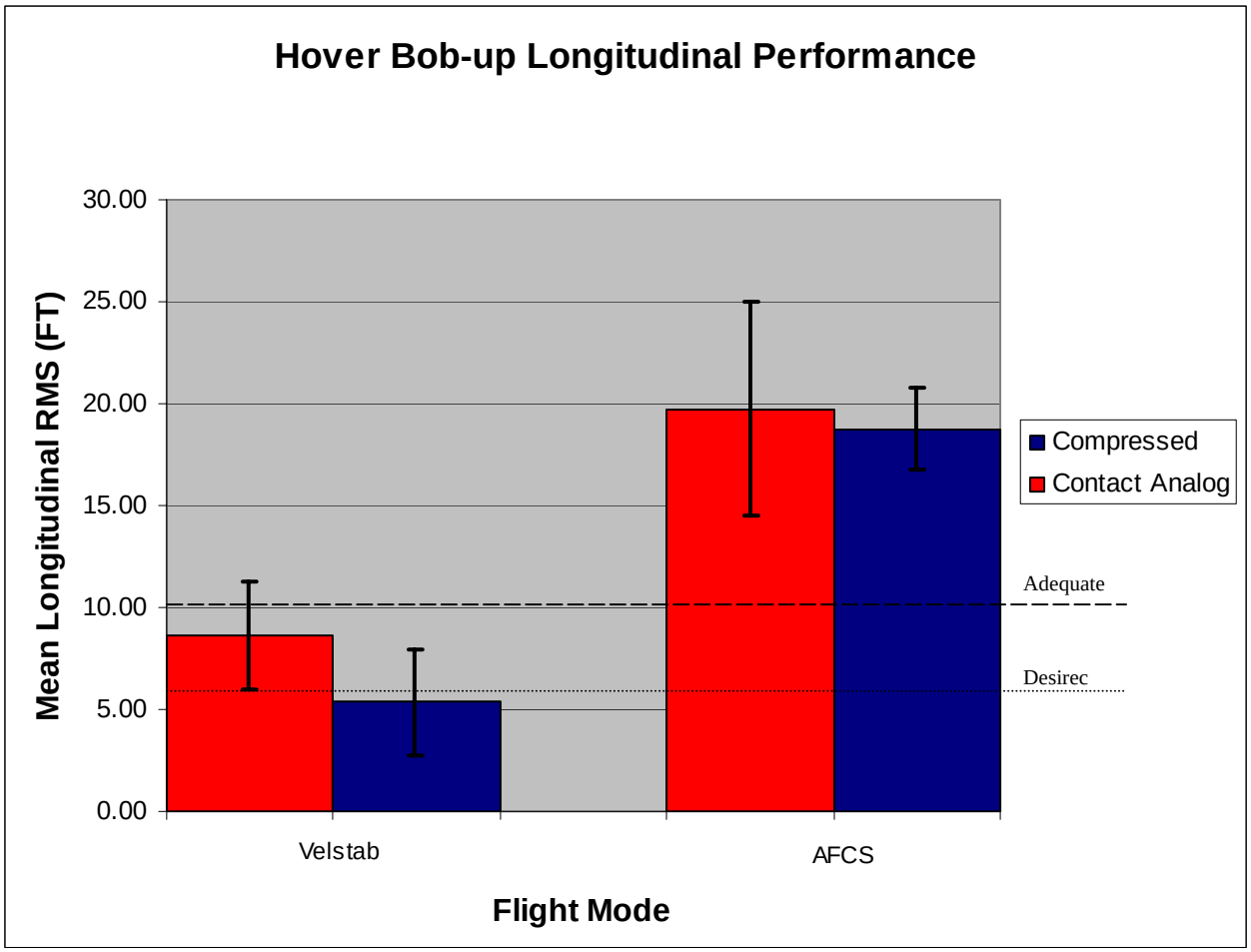

Figure 14. Effect of flight mode on Hover Bob-up longitudinal RMS performance.

It is significant to note that only Hover Bob-up maneuvers conducted in VelStab flight mode, using the Compressed symbology, fostered performances within desired tolerance range (M = 5.36 ft). However, maneuvers performed in VelStab flight mode using Contact Analog symbology (M = 8.60 ft) yielded longitudinal RMS performances within adequate range. Inadequate performances for the longitudinal RMS parameters given (M = 18.75 ft; M = 19.75 ft, respectively) were recorded for maneuvers executed in AFCS flight mode in both Compressed and Contact Analog symbology. Overall, longitudinal RMS deviation was greatest when operating in AFCS flight mode using Contact Analog symbology.

3.4.2 Lateral Performance

A main effect of flight mode was found, F (1, 5) = 29.46, $p < 0.01$ such that AFCS flight mode (M = 26.92 ft) yielded significantly greater lateral deviation than VelStab flight mode (M = 6.50 ft). The performance standard called for maintaining longitudinal position ±6 ft for desired and ±10 ft for adequate performance. No significant interaction of symbology and flight mode was found. No other significant effects were found (fig. 15).

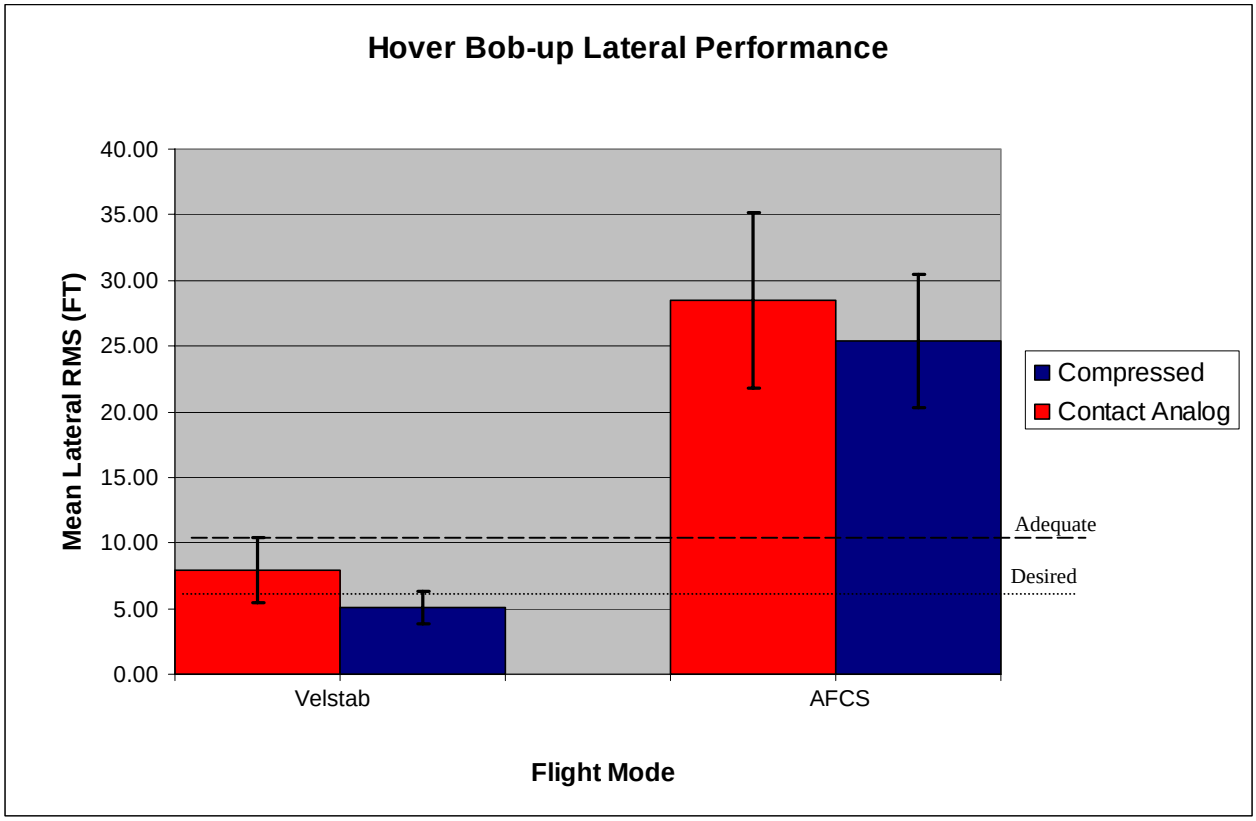

Figure 15. Effect of flight mode on Hover Bob-up lateral RMS performance.

In summary, only Hover Bob-up maneuvers conducted in VelStab flight mode using the Compressed symbology fostered performances within desired range (M = 5.09 ft) for the specified lateral RMS parameters. Maneuvers performed in VelStab flight mode using Contact Analog symbology yielded adequate performances (M = 7.90 ft). However, maneuvers performed in AFCS flight mode in both Compressed and Contact Analog symbology yielded inadequate performances for the lateral RMS parameters given (M = 25.34 ft; M = 28.50 ft, respectively). Overall, lateral RMS was greatest when operating in AFCS flight mode using Contact Analog symbology.

3.4.3 Altitude Performance

A main effect of symbology was found, F (1, 5) = 24.60, $p < 0.01$, such that Contact Analog symbology (M = 5.17 ft) yielded significantly greater final altitude deltas than Compressed symbology (M = 3.12 ft) (see fig.16).

The performance standard called for climbing to a specified altitude ±5 ft for desired and ±10 ft for adequate performance. Although the data correctly showed desired to adequate performance in AFCS, altitude control was typically not in a steady state when the data were taken. Pilot comments, data plots, and HQRs clearly indicate that pilots found altitude management to be a high-workload task. Performance was characterized by a dynamic overshoot of the target altitude followed by a tendency to overcontrol the vertical axis while attempting to manage the vertical rate. Sensitivity of the collective flight control was cited by pilots as a contributing factor. No significant interaction of symbology and flight mode was found. No other significant effects were found.

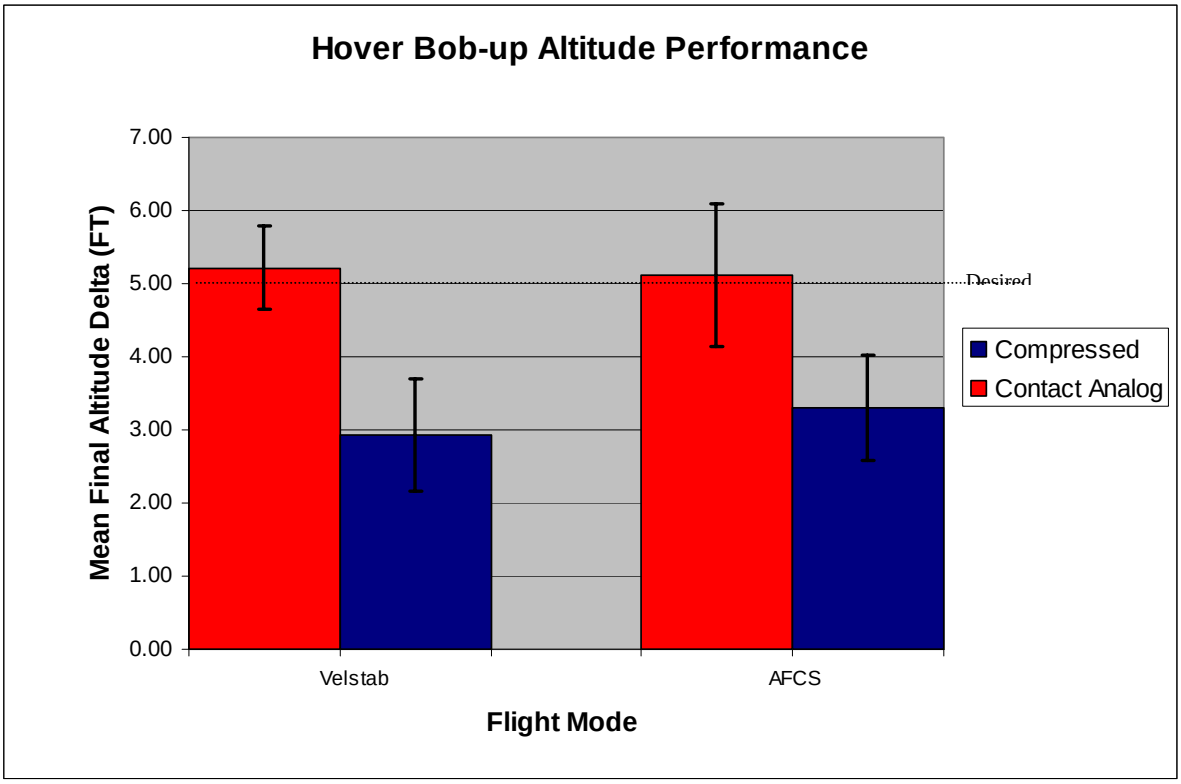

Figure 16. Effect of symbology on Hover Bob-up altitude performance.

In summary, Hover Bob-up maneuvers executed only while using Compressed symbology in either VelStab (*M* = 2.93 ft) or AFCS flight modes (*M* = 3.30 ft) yielded final altitude deltas within desired range. However, maneuvers performed with Contact Analog symbology in VelStab (*M* = 5.22 ft) and AFCS (*M* = 5.12 ft) yielded adequate performances for the altitude parameters given. These statistics accurately reflect the data collected. However, the statistical results must be tempered with observed performance in the AFCS flight mode as reflected in the data plots, pilot comments, and HQR ratings.

3.4.4 Heading Performance

A significant interaction of symbology and flight mode was found, F (1, 5) = 7.40, $p < 0.05$ such that final heading delta did not significantly vary within flight modes when using Contact Analog symbology, but did when using Compressed symbology (fig. 17). Heading performance in AFCS flight mode using Compressed symbology revealed larger final heading deltas than when operating in VelStab flight mode, *t (one-tail)*(5) = 2.12, p = 0.05. A main effect of flight mode was found, F (1, 5) = 8.22, $p < 0.05$, such that AFCS flight mode (*M* = 1.95) yielded significantly greater final heading deltas than VelStab flight mode (*M* = 1.38). The performance standard called for establishing a stabilized heading ±4° for desired and ±6° for adequate performance. No other significant effects were found.

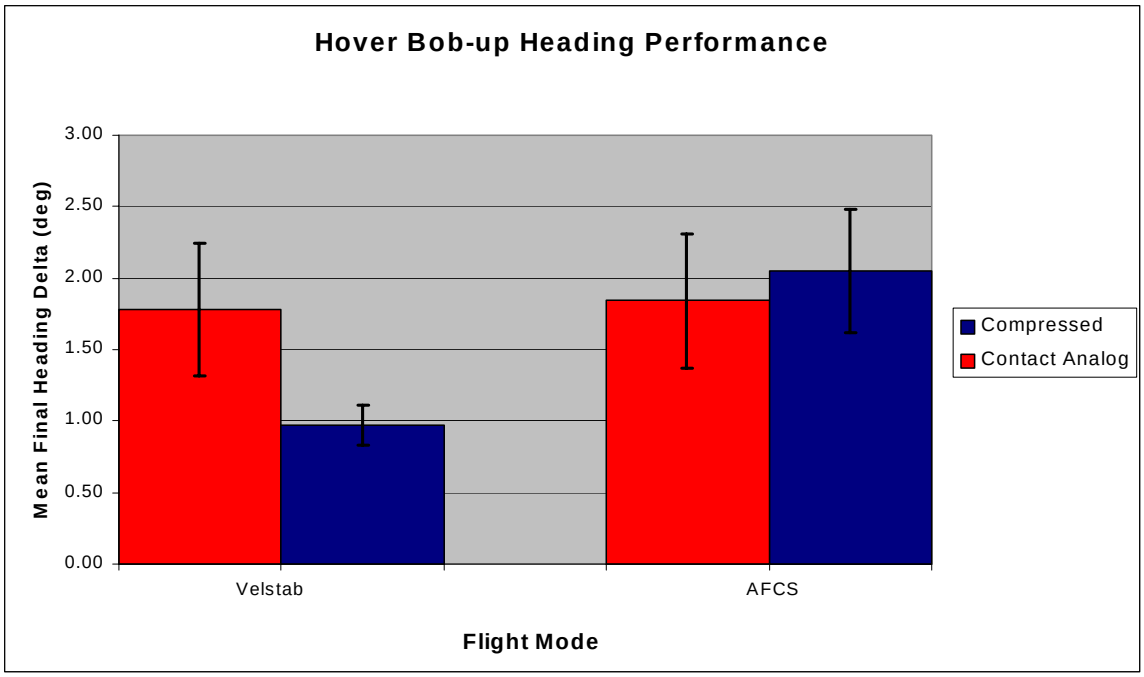

Figure 17. Effect of flight mode on Hover Bob-up heading performance.

It should be noted that final heading performances for Hover Bob-up maneuvers across all experimental conditions were recorded with means for final heading delta below ±4°. Therefore, all final heading performance data across conditions were deemed desired performances. Overall, the mean final heading delta was largest when operating in AFCS flight mode using compressed symbology.

3.4.5 Time Performance

A marginal main effect of flight mode was found, F (1, 5) = 6.52, p = 0.05 such that AFCS flight mode (M = 21.12 sec) yielded significantly longer times to stabilize than VelStab flight mode (M = 13.61 sec) (fig. 18). The performance standard called for establishing a stabilized heading within ±15 seconds for desired and ±20 seconds for adequate performance. No significant interaction of symbology and flight mode was found. No other significant effects were found.

To summarize, only Hover Bob-up maneuvers conducted in VelStab flight mode recorded mean performances within desired range, regardless of symbology. Maneuvers performed in AFCS flight mode using Compressed symbology yielded adequate performances for the time parameters given (M = 19.71 sec). However, maneuvers performed with Contact Analog symbology in AFCS flight mode yielded inadequate performance levels. Overall, mean time to stabilize after executing a Hover Bob-up maneuver was greatest when operating in AFCS flight mode using Contact Analog symbology (M = 22.52 sec).

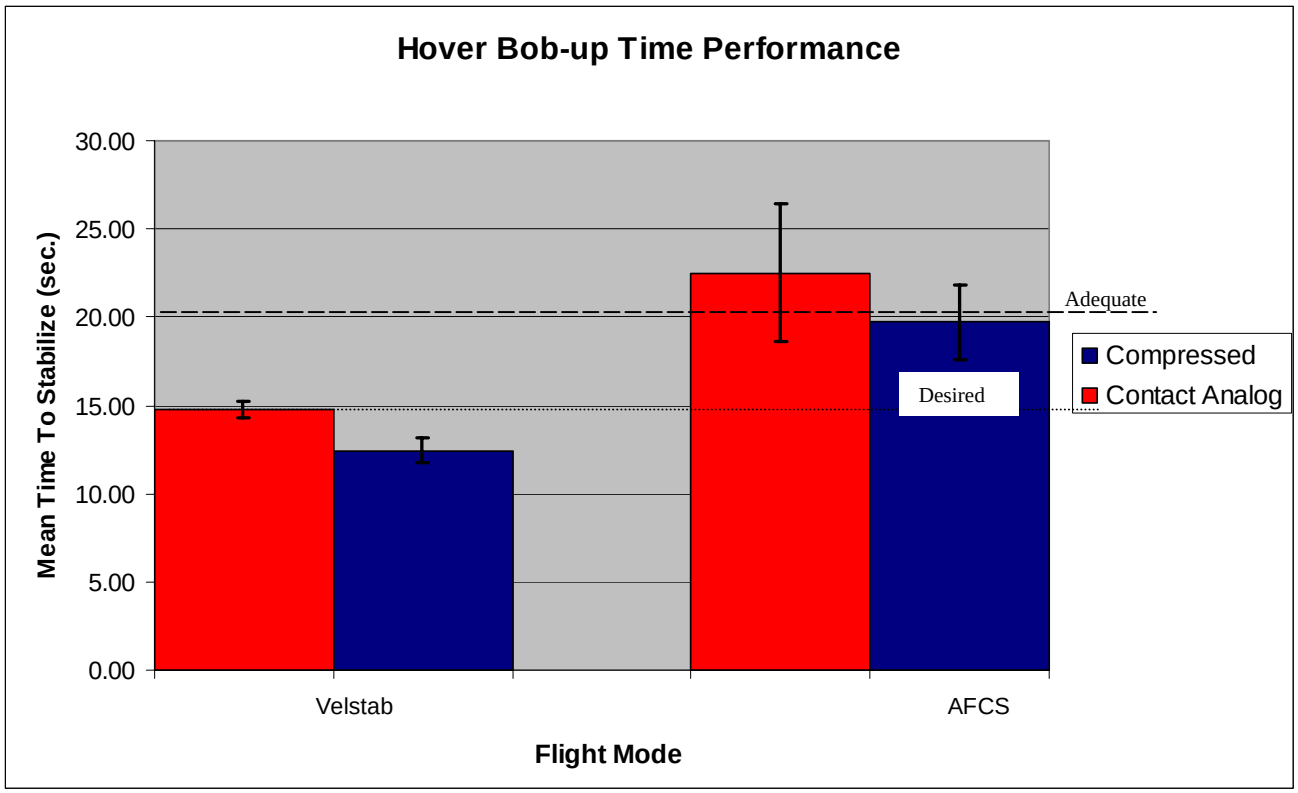

Figure 18. Effect of flight mode on Hover Bob-up time performance.

3.5 Transient Turn Maneuver

Separate 2 x 2 x 4 x 3 within-subjects repeated measures ANOVAs (Symbology x Flight Mode x Block x Replication) were conducted on altitude, heading, and time performance data. Planned comparisons were examined on symbology and flight-mode variables as related to each subset of performance data independently.

3.5.1 Altitude Performance

A marginal significant interaction of symbology and flight mode was found, F (1, 4) = 6.47, $p < 0.06$, such that mean altitude deviation significantly varied as a result of symbology within AFCS flight mode, but did not within VelStab flight mode (fig. 19). Altitude performance in AFCS flight mode, using Contact Analog symbology (M = 31.45 ft), yielded greater mean altitude deviation than Compressed symbology (M = 13.65 ft), t (4) = 2.53, p = 0.06. A marginal main effect of symbology was also found, F (1, 4) = 6.12, p = 0.07, such that Compressed symbology (M = 8.60 ft) yielded smaller altitude deviations than Contact Analog (M = 17.38 ft). A main effect of flight mode was found, F (1, 4) = 11.90, $p < 0.05$, such that AFCS flight mode (M = 38.28 ft) yielded significantly higher deviations in altitude performance than VelStab flight mode (M = 3.42 ft).

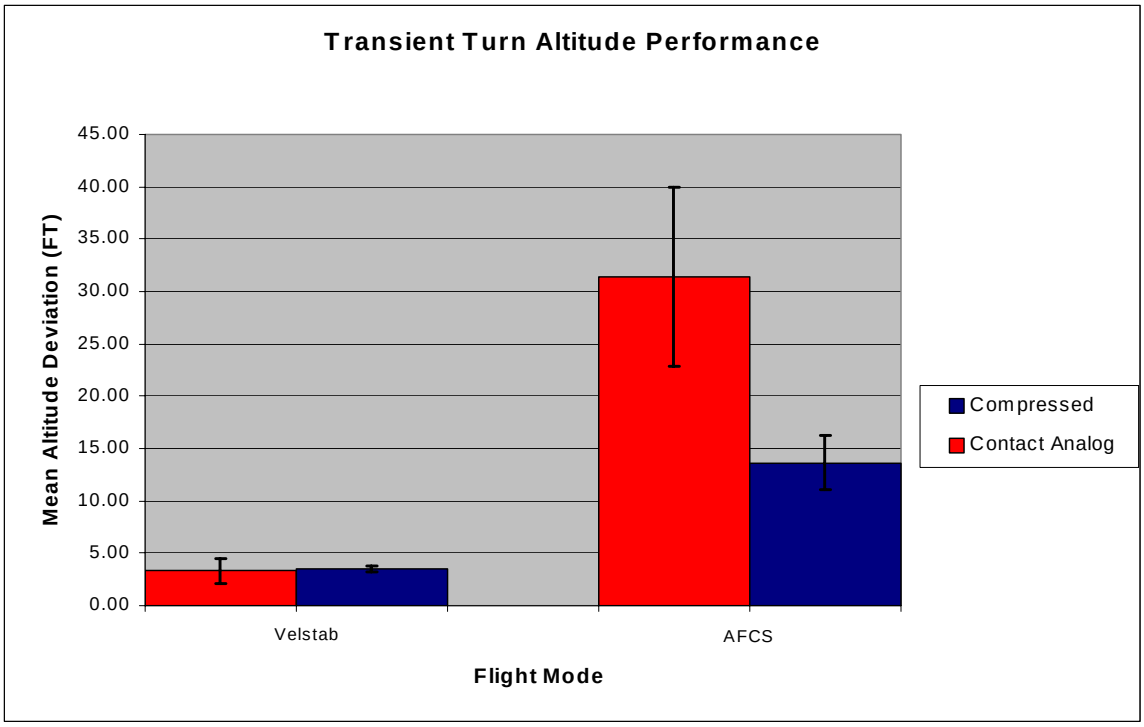

Figure 19. Effect of flight mode on Transient Turn altitude performance.

It should be noted that mean altitude deviation for Transient Turn maneuvers across all experimental conditions were recorded with means below 50 ft. The maneuver standard called for maintaining altitude ±50 ft for desired and ±100 ft for adequate performance. Therefore, altitude-deviation data across all conditions were deemed desired performances. However, within the range of desired performance, there may or may not be implications for completing a transient turn with mean altitude deviation less than 4 ft (VelStab flight mode) versus greater than 30 ft (Contact Analog AFCS). Altitude Hold ON in the VelStab mode accounted for the small deviations from the performance standard. Additionally, the differences in altitude deviation between symbologies should be reviewed. Operational considerations are warranted for appropriate interpretation of these data.

3.5.2 Heading Performance

A main effect of flight mode was found, F (1, 4) = 12.19, $p < 0.05$ such that AFCS flight mode (M = 1.23°) yielded significantly greater heading deviation than VelStab flight mode (M = 0.78°) (fig. 20). The maneuver standard called for establishing a stabilized heading ±2° for desired and ±5° for adequate performance. No significant interaction of symbology and flight mode was found. No other significant effects were found.

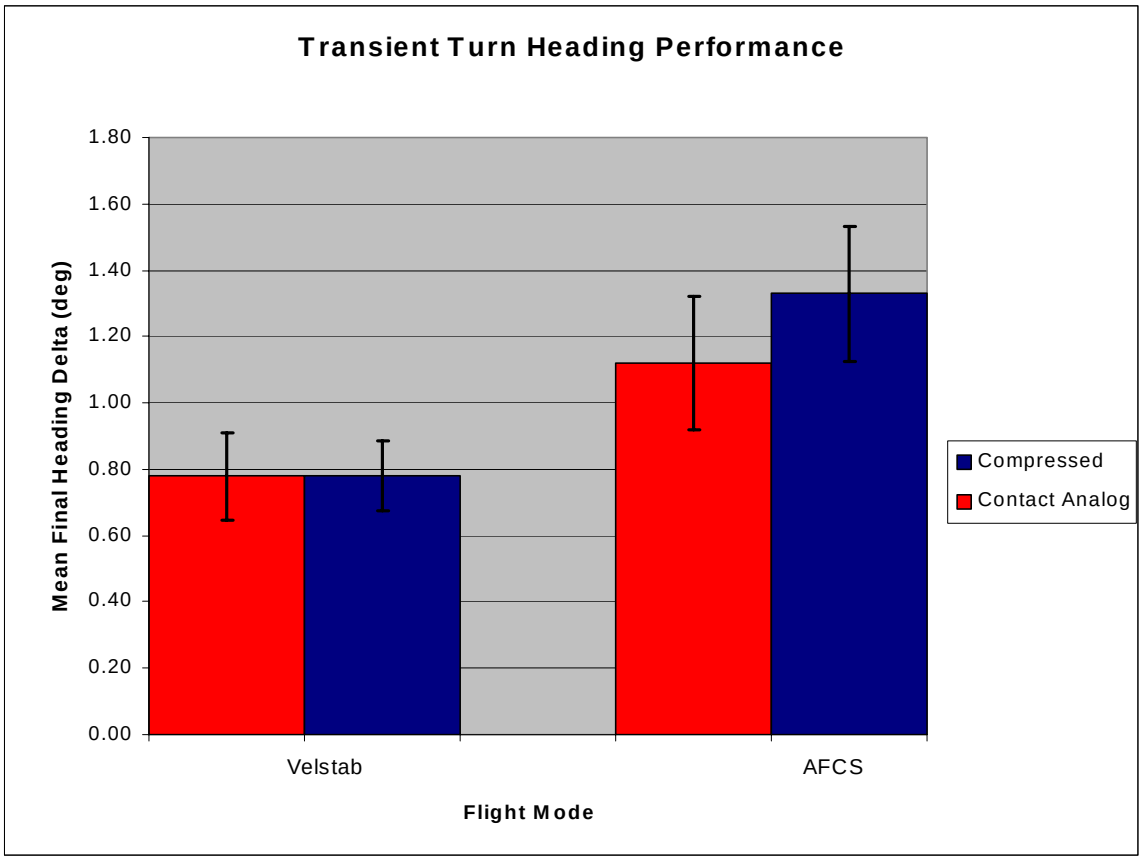

Figure 20. Effect of flight mode on Transient Turn heading performance.

In summary, mean heading deviation for Transient Turn maneuvers across all experimental conditions were recorded with means below ±2° deviation. Therefore, heading-deviation data across all conditions were deemed desired performances. Although statistical differences were found between flight modes, operational impact cannot be inferred from the data.

3.5.3 Time Performance

No significant interaction of symbology and flight mode was found (fig. 21). No other significant effects were found.

In summary, mean completion times for the Transient Turn maneuver were deemed desired performances for all flight modes and symbology sets.

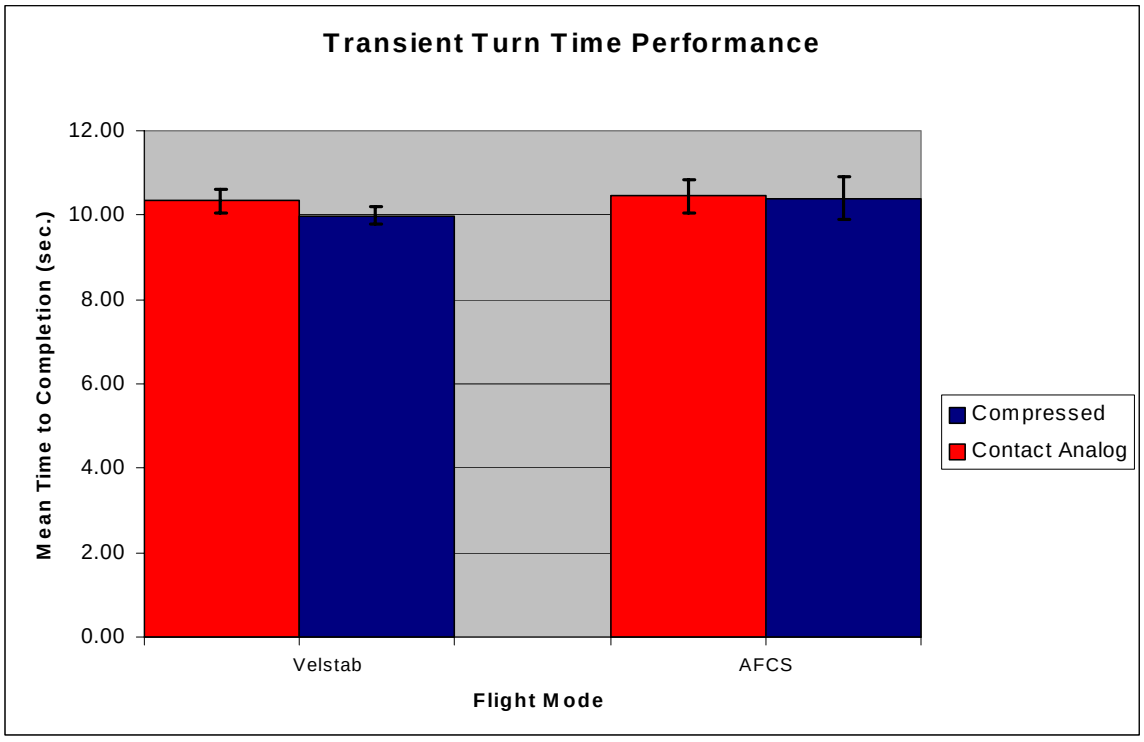

Figure 21. Effect of flight mode on Transient Turn time performance.

3.6 Summary of Objective Statistical Analysis Results

Statistical results have been presented for three maneuvers (Hover Turn, Hover Bob-up, Transient Turn). Data concerning pilot performance against specified performance goals while flying in two different flight control modes (VelStab and AFCS) using two different symbology sets (Contact Analog and Compressed) showed the following summarized results presented for each performance parameter (Heading, Altitude, Time, Position):

3.6.1 Heading Summary

Desired heading performance was generally achieved for all three maneuvers in both flight control modes using both symbol sets. Overall, pilots achieved slightly better performance flying in VelStab over AFCS for the Bob-up and Transient Turn maneuvers. Differences in flight control mode were not statistically significant for the Hover Turn. Little difference was observed between Contact Analog and Compressed symbology. Pilots did, however, perform slightly better (1°) in Contact Analog AFCS flight mode over Contact Analog VelStab for the Hover Turn maneuver. Potential contributing factors were excessive speed of Contact Analog heading-tape movement and scaling. Also, the VelStab heading hold feature tended to "hunt" for a final heading to lock on to, resulting in a slight 1° to 2° oscillation before locking on a final heading to hold. A probable contributor to good pilot performance for this parameter was that pilots knew the focus of this simulation was the heading tape. This fact may have resulted in pilots placing a workload management priority and mental focus on managing this individual parameter before all others.

3.6.2 Altitude Summary

Pilot performance met desired standards or slightly exceeded desired (Bob-up) for each of the three maneuvers while in VelStab flight mode, with negligible difference between Contact Analog and Compressed symbology. However, this was not the case in the AFCS flight mode. Data showed that although performance was within the adequate range, the difference between Contact Analog and Compressed symbology was significant. Compressed symbology outperformed Contact Analog by margins of 2 to 3 times better accuracy for all three maneuvers. Although the data correctly showed adequate performance in AFCS for the Bob-up maneuver, pilot comments, data plots, and HQRs clearly indicate that pilots found altitude management to be a high-workload task. Performance was characterized by a dynamic overshoot of the target altitude followed by a tendency to overcontrol the vertical axis while attempting to manage the vertical rate. Sensitivity of the collective flight control was cited by pilots as a contributing factor.

3.6.3 Lateral and Longitudinal Position

Position maintenance was measured only for the hovering tasks (Hover Turn and Bob-up). The results were consistent for both maneuvers showing pilots able to achieve desired performance in the VelStab mode, with Compressed symbology outperforming Contact Analog by a small margin. Similarly, the results were consistently unacceptable for both maneuvers in the AFCS flight mode. Pilots typically exceeded the allowable adequate performance limit by more than double the adequate limit, with Compressed symbology performing better than Contact Analog by a significant margin for the Hover Turn and by a smaller margin for the Bob-up maneuver. Although the Aircrew Training Manual for the Comanche remains in draft, it is unlikely that the recorded performance for this maneuver would meet the standards using Apache as a basis for comparison. The lack of hover position symbology and the sensitivity of the velocity vector and acceleration cue symbology most likely contributed to this poor performance.

3.6.4 Time

Meeting the desired time-maneuver standard was not an issue while operating in the VelStab flight control mode for either symbol set. Time standards for the Transient Turn were also met in both VelStab and AFCS while flying both symbology sets. However, data showed time performance for the hover maneuvers (Hover Turn and Bob-up) while in AFCS flight mode to be a mixed result. Both symbology sets exceeded the time standard for the Hover Turn by approximately 4 seconds. The Bob-up showed Compressed symbology barely achieving adequate, and Contact Analog was unacceptable by approximately 2.5 seconds. The suspected cause of the difference between VelStab and AFCS was managing the added workload of keeping altitude and position, causing the pilot to slow the maneuver down to a point where the time exceeded adequate standards for the maneuver.

3.6.5 Summary

Further research should be conducted where objective data results indicate a need for improvement. The areas requiring attention are those where the symbology implementation, the flight control system, or a combination of both caused pilot performance to exceed adequate performance standards. These areas are clearly identified in this report. Pilot comments found at the end of this report should be examined to better understand the factors influencing pilot performance.

3.7 Subjective Performance Ratings

Subjective HQRs and NASA-TLX ratings were collected on all four evaluative maneuvers. Ratings were collected from six pilots for Hover Turn, Hover Bob-up, and Traffic Pattern, less one for Transient Turn. Mean comparisons of subjective data were conducted on verbal HQRs given. Comparisons of NASA-TLX ratings summarized workload demands for Hover Bob-up, Hover Turn, and Transient Turn only. Ratings of the Traffic Pattern were excluded because the pilots had difficulty in designating a single rating for a two-part maneuver with disparate levels of intensity. For the purpose of summarization, NASA-TLX ratings have been collapsed across the six dimensions assessed (mental demand, physical demand, time demand, effort level, frustration level, and overall performance).

3.8 Handling Quality Ratings

In a comparison of means calculated for HQRs, AFCS flight mode yielded higher HQRs regardless of symbology tested. Within VelStab and AFCS flight modes, HQRs were higher with Contact Analog symbology ($\underline{M}$ = 4.15 > 3.69; $\underline{M}$ = 5.47 > 5.15, respectively). Both Contact Analog and Compressed symbology sets were rated as possessing "deficiencies warranting improvement," with scores ranging low to high, 3.69 to 5.47 (low/Compressed VelStab, high/Contact Analog AFCS). It should be noted that a rating of 3 and under is categorically different because the aircraft handling is considered satisfactory without improvement. Overall, Compressed symbology in the VelStab flight mode produced the lowest mean HQR, encompassing mixed ratings of satisfactory handling and needing improvement. All other symbology/flight mode combinations yielded higher HQRs, which characterized opinions that deficiencies in aircraft handling would need improvement. (See fig. 22.)

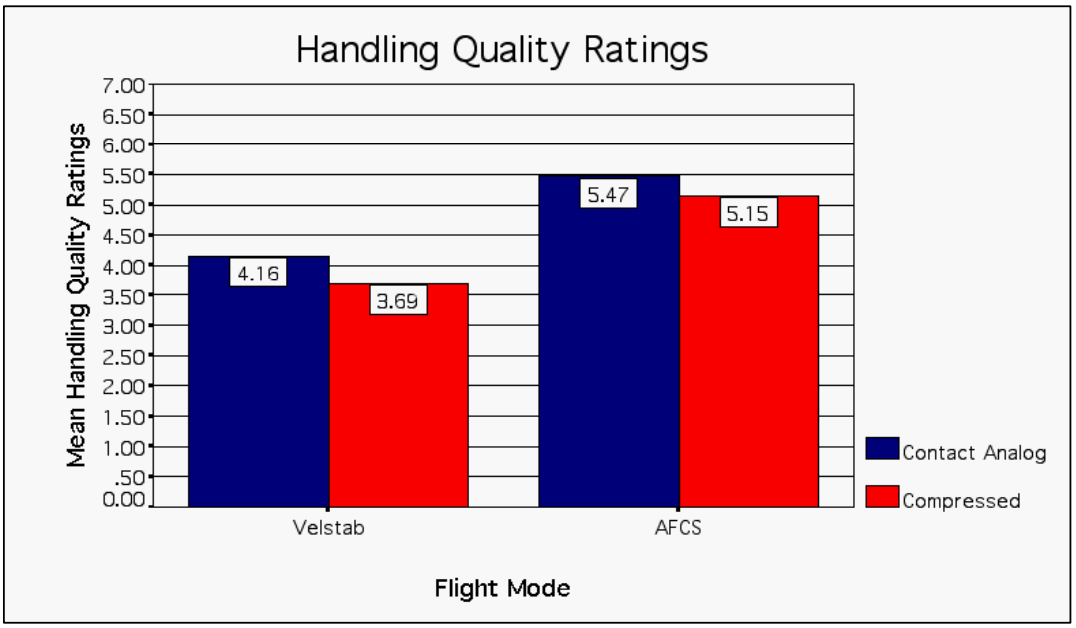

Figure 22. Mean HQRs for Hover Turn, Hover Bob-up, Transient Turn, and Traffic Pattern maneuvers.

NOTE: The authors of this report recognize that averaging HQRs across different tasks is not recommended and is objected to by many in the flight controls development community. HQRs should be accompanied by pilot comments to fully understand their implications. For this reason, the detailed analysis section that follows matches the HQR and the pilot comments for a more detailed understanding of the simulation results.

3.9 Compressed vs. Contact Analog

HQRs also showed a marginally significant difference between symbology sets $F(1,5) = 6.45$, $\underline{p} = 0.052$. The average HQR for Contact symbology was nearly 5.0, which translates to moderately objectionable deficiencies, with adequate performance requiring considerable pilot compensation. Compressed symbology was rated better at approximately 4.5, which is on the border between minor and moderate deficiencies and between desirable and adequate performance. Refer to figure 23.

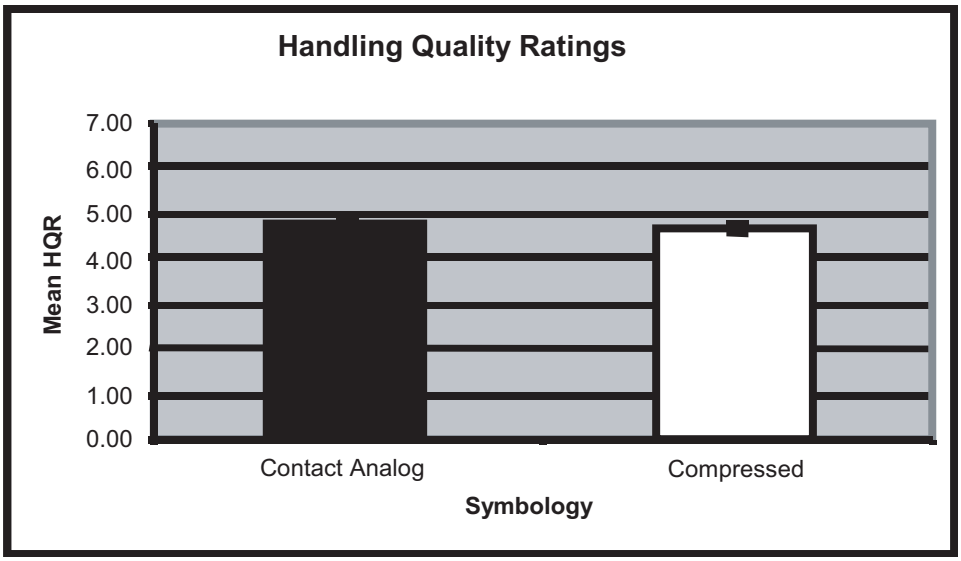

Figure 23. HQR Contact Analog vs. Compressed.

3.10 NASA-TLX Ratings

When comparing means calculated for NASA-TLX ratings, AFCS flight mode yielded higher demand ratings regardless of symbology tested. Within VelStab and AFCS flight modes, scores were higher with Contact Analog symbology ($\underline{M}$ = 2.88 > 2.49; $\underline{M}$ = 3.98 > 3.78, respectively). Mean TLX scores across dimensions repeated the pattern of findings in objective performance measures, ranging low to high, 2.49 to 3.98 (low/Compressed VelStab, high/Contact Analog AFCS). It should be noted that ratings given for symbology sets in VelStab flight mode can be described as "Neutral" (3) to "Low" (2), whereas AFCS flight mode yielded ratings described as "Neutral" (3) to "High" (4). Overall, Compressed symbology in the VelStab flight mode was rated as the least demanding on resources, closely followed by ratings for Contact Analog in the VelStab mode. In a similar pattern, TLX ratings for maneuvers completed in the AFCS mode yielded a higher level of resource demand, with even slighter differences between Contact Analog and Compressed symbology sets. (See fig. 24.)

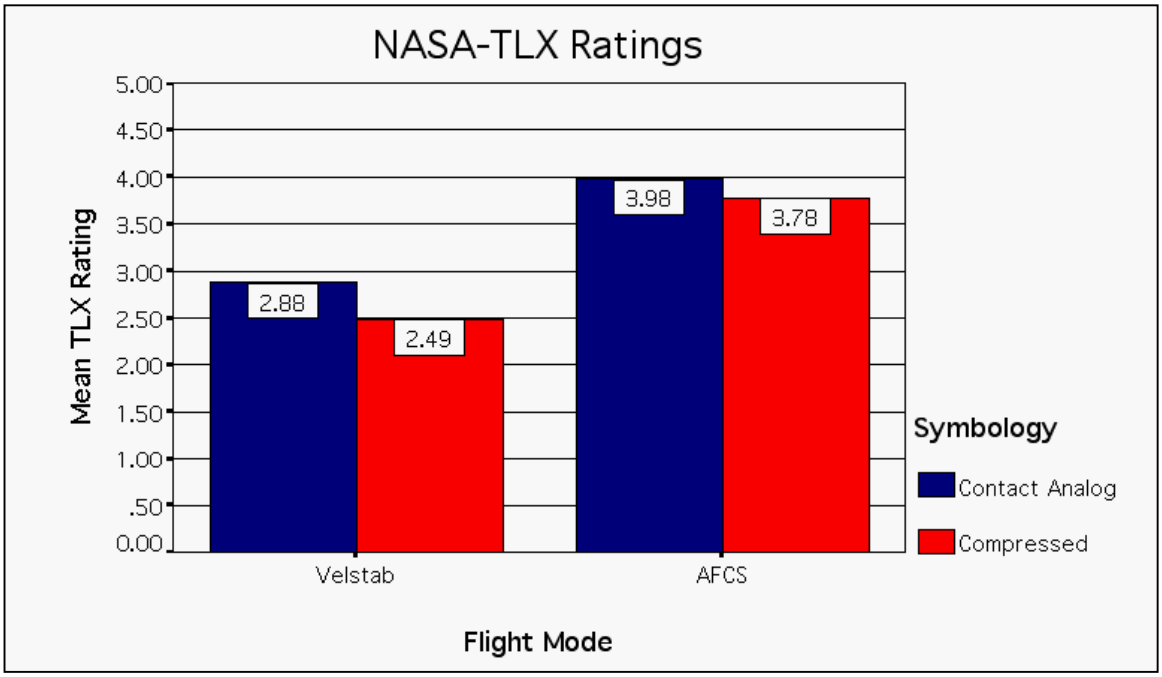

Figure 24. Mean NASA TLX ratings for Hover Turn, Hover Bob-up, and Transient Turn. NASA TLX ratings were defined by a 5-point scale: 1 = Very low, 2 = Low, 3 = Neutral, 4 = High, and 5 = Very high.

TABLE 3. TOLERANCE LEVELS: DEPENDENT MEASURES SUMMARY

Symbology/Flight Mode				
Maneuver	**Contact Analog VelStab**	**Compressed VelStab**	**Contact Analog AFCS**	**Compressed AFCS**
Hover Bob-up	Long. RMS (A) Lat. RMS (A) Altitude (A) Heading (D) Time (D)	Long. RMS (D) Lat. RMS (D) Altitude (D) Heading (D) Time (D)	Long. RMS (U) Lat. RMS (U) Altitude (A) Heading (D) Time (U)	Long. RMS (U) Lat. RMS (U) Altitude (D) Heading (D) Time (A)
Transient Turn	Altitude (D) Heading (D) Time (D)	Altitude (D) Heading (D) Time (D)	Altitude (D) Heading (D) Time (D)	Altitude (D) Heading (D) Time (D)
Hover Turn	Long. RMS (D) Lat. RMS (D) Altitude (D) Heading (D) Time (D)	Long. RMS (D) Lat. RMS (D) Altitude (D) Heading (D) Time (D)	Long. RMS (U) Lat. RMS (U) Altitude (A) Heading (D) Time (U)	Long. RMS (U) Lat. RMS (U) Altitude (A) Heading (D) Time (U)

Tolerance-level color-coding as follows:
Desired (D)
Adequate (A)
Inadequate (U)

SECTION 4. ANALYSIS OF HQRS AND PILOT COMMENTS

4.1 Detailed Analysis Section Overview

This section presents a detailed analysis of pilot performance for each of the four simulation test maneuvers. Each maneuver is described first. The mean handling qualities ratings are presented for the two different flight control systems and two symbology sets flown during the simulation. The HQRs are followed by a summary of the most repeated pilot comments concerning each symbology set and flight control system. Finally, selected data run sheets are presented and the results are analyzed in detail. All of the HQR comments are reflected in one or more of the data sheets. Not all comments may have been captured in the data sheets selected for detailed analysis. For that reason, readers interested in tracing each comment to specific data should review the full set of data run sheets and pilot comments that are included in the appendices to this report.

Figure 25 describes the Hover Turn maneuver.

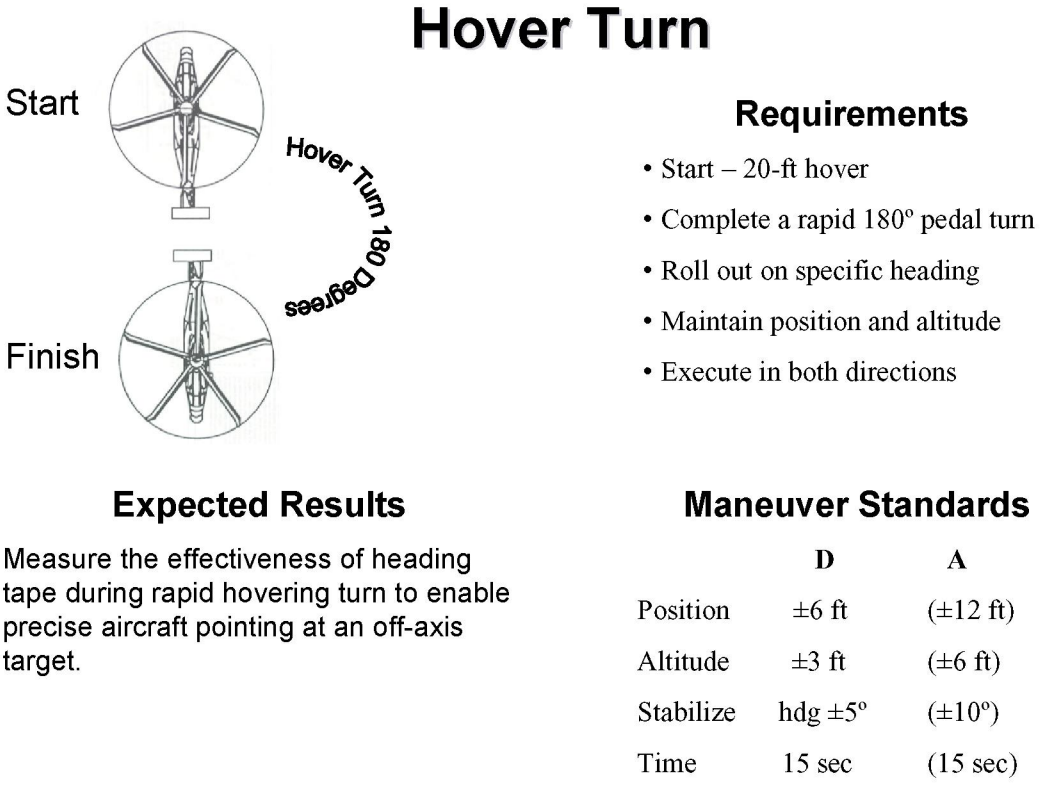

Figure 25. Hover Turn.

4.2 Hover Turn HQR

4.2.1 Contact Analog Symbology – VelStab Flight Control Mode

The mean HQR for the Hover Turn with VelStab was 3.6, with half the pilots rating the maneuver a 3. This translates to a Cooper/Harper rating of between HQR 3—Fair, some mildly unpleasant deficiencies, minimal compensation required, and HQR 4—Minor deficiencies, desired performance required considerable pilot compensation. Pilots predominantly achieved desired performance on this maneuver with an occasional adequate rating.

Pilot comments: The most repeated pilot comments concerning the symbology and the flight control handling qualities were as follows:

- Five out of six pilots reported that the heading tape was unreadable during the hover turn because it scrolls across the screen too quickly. The heading tape can be read only when the turn slows down.
- Five out of six pilots reported a tendency to overshoot the desired heading.
- Four pilots reported that the digital heading was not useful as an analog predictor of when to roll out of the hover turn on the desired heading because it scrolled too quickly. The digital heading was difficult to read during the fast yaw rate.
- Two pilots reported that the inability to see the current heading and desired rollout heading simultaneously resulted in the need to focus on the heading tape almost exclusively, leaving little attention span for other axes.
- Two pilots commented that the heading tape moves faster than the aircraft yaw rate, a situation that leads to mental confusion. Heading-tape movement with head movement gives the feeling that aircraft yaw rates are greater than actual rates.
- Two pilots reported that they could not see enough of the heading (only approximately 30° in the field of view (FOV)) to accurately predict when to stop the hover turn on the desired heading.

4.2.2 Contact Analog Symbology – AFCS Flight Control Mode

The mean HQR for the Hover Turn with AFCS was 6.6, with half the pilots rating the maneuver a 7. This translates to a Cooper/Harper rating of between HQR 6—Very objectionable but tolerable deficiencies, adequate performance requires extensive pilot compensation; and HQR 7—Major deficiencies, adequate performance not obtainable with maximum pilot compensation, controllability not in question. This is a twofold decrease in acceptability as compared to the same maneuver in the VelStab mode.

Pilot comments: The most repeated pilot comments concerning the symbology and the flight control handling qualities are as follows:

- Six out of six pilots reported they were not able to meet adequate standards for either position or altitude, or both.
- All six pilots reported that collective control was too sensitive to minor control input. They reported that the outcome of collective control input was unpredictable and that aircraft vertical damping was too light.

- Five out of six pilots reported a tendency to overshoot desired altitude because of the collective sensitivity.
- Four of six pilots commented that no symbology was available for maintaining hover position. The velocity vector and acceleration cue symbols were ineffective in maintaining hover position.
- Three pilots commented that the heading tape moves too fast to be readable during a rapid hover turn. The Contact Analog heading tape is not a good analog cue for heading.
- Two pilots reported high workload in completing the maneuver.
- One pilot commented that the Earth-referenced heading tape caused disorientation and caused inappropriate flight control input.
- One pilot reported that the altitude predictor is confusing and distracting.

4.2.3 Compressed Symbology – VelStab Flight Control Mode

The mean HQR for the Hover Turn with VelStab was 3.5, with half the pilots rating the maneuver a 3. This translates to a Cooper Harper rating of between HQR 3—Fair, some mildly unpleasant deficiencies, minimal pilot compensation required; and HQR 4—Minor deficiencies, desired performance required considerable pilot compensation. Pilots predominantly achieved desired performance on this maneuver with an occasional adequate rating. The 3.5 rating is virtually the same (one-tenth of a point better) than the VelStab rating using Contact Analog symbology.

Pilot comments: The most repeated pilot comments concerning the compressed symbology and the VelStab flight control handling qualities were as follows:

- All six pilots reported no difficulty in meeting desired performance in heading and altitude (VelStab has ALT HOLD).
- Half the pilots reported they could not hold hover position to meet standards in spite of the fact that VelStab Position Hold was engaged. No symbology is available for precisely maintaining hover position. The velocity vector and acceleration cues are not usable for maintaining a hover position to meet adequate performance standards.
- Three of six pilots commented they had a slight tendency to overshoot heading.
- Two pilots commented that they liked the Compressed heading tape because the target heading was visible during the entire hover turn. This fact reduces pilot cross-check workload, freeing time to manage other axes.
- Two pilots commented that VelStab managed altitude and position, making it easier to concentrate on heading.

4.2.4 Compressed Symbology – AFCS Flight Control Mode

The mean HQR for the Hover Turn with AFCS was 6.1, with half the pilots rating the maneuver a 7. A Cooper/Harper rating of HQR 6 translates to very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation. This is slightly less than a twofold decrease in acceptability as compared to the same symbology in the VelStab flight control mode. Half the pilots rated the flight control mode and symbology an HQR 7—Major deficiencies, adequate performance not obtainable with maximum pilot compensation. Controllability was not in question. This is similar to the ratings for AFCS using the Contact Analog symbology. Although

pilots had a more difficult time with this maneuver in AFCS vs. VelStab, the HQR rating differences between Contact Analog and Compressed symbology were not significantly different.

Pilot comments: The most repeated pilot comments concerning the symbology and the flight control handling qualities were as follows:

- All six pilots reported that precise altitude control involved high workload and was difficult to manage. The lightly dampened collective control of the vertical axis caused a tendency to overshoot and undershoot the desired altitude. Collective response was too sensitive and unpredictable.
- Five of six pilots commented that the Compressed heading tape made achieving desired heading standards easy. The Compressed heading-tape design required less pilot workload and cross-check time because the target heading was in view during the entire turn.
- Four of six pilots reported this maneuver to involve very high workload in managing multiple axes simultaneously.
- Three pilots commented on the lack of hover-position symbology. They further commented that the velocity vector and acceleration cue are not adequate for maintaining a precise hover position, and they were, therefore, unable to maintain hover position to adequate standards.

4.3 Pilot Performance Data Plots

Each of the four maneuvers flown during this simulation had 16 recorded data flights (8 Contact Analog and 8 Compressed) per pilot. The total number of data runs for this maneuver for all 6 pilots was 96. Only selected data flights are presented in this section. The following runs show examples of pilot performance in completing the Hover Turn maneuver with both Contact Analog and Compressed symbology and in the VelStab and AFCS flight control modes. The runs selected for presentation are those that most graphically demonstrate either the performance difficulties pilots had with the maneuver or that visually demonstrate the pilot comments concerning the maneuver. A complete set of data charts is available upon request.

4.3.1 Contact Analog, VelStab, Run 15

Run 15 data are representative of pilot performance during this maneuver. It is clear that VelStab Position Hold ON was able to maintain aircraft position over the ground to adequate standards on this particular maneuver. However, this was not true in every case, as noted in Runs 75 and 238. Altitude Hold did a reasonable job of maintaining altitude to desired standards with a small 3-ft variance, and there was a 15° overshoot in heading that was corrected within the desired time.

4.3.2 Contact Analog, AFCS, Run 29

This run, with the same pilot as Run 15, clearly shows the increased level of difficulty experienced by the pilot when the Altitude and Position Hold features of VelStab were not available. Adequate position standards were exceeded by a wide margin of 28 ft. The pilot demonstrated difficulty in managing altitude with oscillations of as much as 12 ft, but was within adequate/desired standards when the time for the maneuver expired. Heading was overshot by approximately 8° and held.

4.3.3 Contact Analog, VelStab, Run 238

This run is included to show that VelStab was not capable of holding position on every run. Adequate standards for position was ±12 ft. The Y position on this run was 19 ft. Other runs showed similar numbers. Aggressiveness of the maneuver may possibly have been a determining factor concerning the ability of VelStab to maintain adequate position. This maneuver may saturate the ability of the flight control system to react. Wrist coupling in the SAC may be causing pilots to inadvertently pull the aircraft out of position. The actual cause requires further investigation.

4.3.4 Compressed, VelStab, Run 76

This run was flown again by Pilot 1 for consistency in comparing results. VelStab was able to hold the aircraft position within adequate standards with a maximum variance of 7.5 ft. VelStab Altitude Hold did an excellent job of maintaining desired standards with a variance of only 1 ft during the maneuver. The pilot, using a Compressed heading scale, overshot the target heading by 10° but recovered to the desired heading with the desired time limit.

4.3.5 Compressed, VelStab, Run 75

This run is included to show that VelStab was not capable of holding position on every run. Adequate standard for position was ±12 ft. Both X and Y positions were exceeded on this run. Other runs showed similar numbers. Aggressiveness of the maneuver may possibly have been the determining factor concerning the ability of VelStab to maintain adequate position. This maneuver may saturate the ability of the flight control system to react. Wrist coupling in the SAC may be causing pilots to inadvertently pull the aircraft out of position. The actual cause requires further investigation.

4.3.6 Compressed, AFCS, Run 86

Pilot 1 was unable to maintain adequate position standards with position variances as great as 50 ft. Altitude was desired at the end of the maneuver but not before altitude oscillations of 15 ft up and 20 ft down nearing ground impact. This was not typical of this pilot's other AFCS runs, where altitude was more controlled. However, this clearly showed a difficulty with vertical oscillations; it clearly shows a struggle with collective sensitivity, which is well documented in the pilot comments. Heading was perfect on this run after other runs showed a tendency to overshoot and then recover to the desired heading during the desired time period.

Figure 26 discusses the turn-to-target Bob-up maneuver.

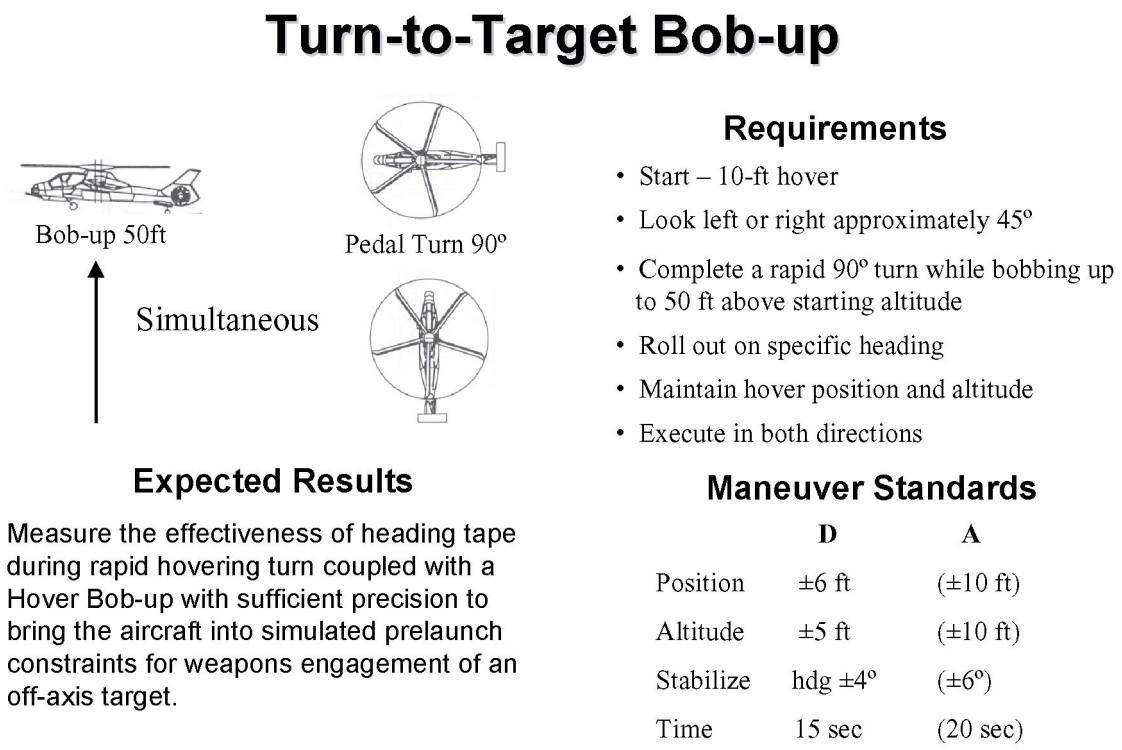

Figure 26. Turn-to-target Bob-up.

4.4 Hover Turn Bob-up

4.4.1 Contact Analog Symbology – VelStab Flight Control Mode

The mean HQR for the Hover Bob-up maneuver with VelStab was 5.3, with a mix of ratings ranging from HQR 3 to HQR 7. A Cooper/Harper rating of HQR 5 translates to moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation. This maneuver was much more difficult than the Hover turn, which had an average HQR of 3.6. This maneuver was much more complex, and it required managing multiple axes (yaw, climb rate, position, time) simultaneously. This is a high-gain task even under good visual conditions, and the increased (worse) HQR ratings reflect the increased difficulty with the available flight controls and symbology.

Pilot comments: The most repeated pilot comments concerning the symbology and the flight control handling qualities covered a broad spectrum and were not particularly concentrated. The most frequent comments were as follows:

- Four out of six pilots commented they had a tendency to overshoot altitude.
- Four pilots reported that VelStab Altitude Hold was slow to react when engaged during the climb. It did not capture the target altitude quickly (floated upward after trigger release), causing overshoot. Leveling off at the desired altitude was not predictable.

- Half of the pilots complained of high pilot workload in the vertical axis. Managing rate of climb was difficult and unpredictable.
- Two pilots reported that combining head movement with yaw led to disorientation and distraction. Pilots reportedly had to keep looking back over the nose of the aircraft to see the lubber line to capture the heading.
- Two pilots commented that the heading tape moved too fast and was unreadable during the turn. Having to concentrate on the heading tape detracted from managing other axes.
- Two pilots reported the digital heading was usable as a cue for heading during the turn, while another pilot reported the digital heading moved too fast to be usable.
- One pilot commented that head-induced heading tape movement could be confused with aircraft movement.
- One pilot thought that the symbology was too spread out in the HMD FOV, resulting in a slower cross check.
- There was one report that the vertical speed indicator (VSI) was difficult to use and interpret.

4.4.2 Contact Analog Symbology – AFCS Flight Control Mode

The mean HQR for the Hover Turn Bob-up with AFCS was 6.3, with half the pilots rating the maneuver a 7. HQR 6 translates to very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation. Half the pilots rated this maneuver HQR 7—Major deficiencies, adequate performance not obtainable with maximum pilot compensation, controllability not in question. This is a 1-point decrease in acceptability as compared to the same maneuver in the VelStab mode. It went from moderately objectionable to very objectionable, requiring extensive pilot compensation.

Pilot comments: The most repeated pilot comments concerning the symbology and the flight control handling qualities are as follows:

- All six pilots reported a tendency to overshoot altitude. The aircraft response to collective input was not predictable, with a tendency to overcontrol the collective input.
- Three pilots reported that managing the vertical axis involved very high workload.
- Two pilots had difficulty using the radar altitude predictor and thought it was distracting.
- Four of six pilots had a tendency to overshoot heading because of the speed of the heading-tape movement. The remaining two pilots reported that capturing the target heading was not difficult.
- Two pilots reported that the rapid movement of the heading tape across the HMD FOV is disorienting. The workload to capture the target heading detracts from managing other axes. A third pilot commented that the heading tape is so far up in the HMD FOV that he had a tendency to tilt his head back to look at it, making other symbology unreadable.
- Four pilots reported an inability to maintain hover position. Drifting out of hover position was due to the fact that the velocity vector and acceleration cues were insufficient for maintaining a precise hover position. There are no symbology cues for position maintenance.

- Two pilots commented on the VSI, with one reporting it to be unusable as a rate cue and the other commenting that the VSI was too sensitive for the lightly damped collective.

4.4.3 Compressed Symbology – VelStab Flight Control Mode

The mean HQR for the Hover Turn Bob-up with VelStab was 4.4, with ratings of the maneuver mixed between HQR 3 and HQR 7. Four of the six individual ratings were HQR 4 or better. Only three were HQR 5 or worse. HQR 4.4 translates to between minor deficiencies, desired performance, considerable pilot compensation, and HQR 5, moderately objectionable deficiencies, adequate performance, considerable pilot compensation. The Compressed symbology was rated a full HQR point better than Contact Analog for this maneuver in the VelStab flight control mode. More pilots achieved desired performance on this maneuver than adequate in most of the measured performance criteria.

Pilot comments: The most repeated pilot comments concerning the Compressed symbology and the VelStab flight control handling qualities were as follows:

- Five out of six pilots commented that altitude control was not predictable. There was a tendency to overshoot altitude.
- Two pilots were unable to achieve a consistent rate of climb.
- In contrast, one pilot out of six reported altitude control required only a minor effort to achieve desirable results and that workload was low. This pilot was believed to be using the SAC for the vertical axis.
- Four pilots reported that heading was easy to control with the Compressed heading tape. Only minor adjustments were required to achieve desired results.
- One pilot thought that the Compressed heading tape reduced cross-check time and workload in heading management.
- Two pilots reported they could not maintain hover position. Two also reported there was no hover position keeping symbology available.
- One pilot reported that VelStab was unable to hold hover position during this maneuver, while one other pilot reported that VelStab held hover position. This apparent conflict may depend on how aggressively the maneuver was performed.

4.4.4 Compressed Symbology – AFCS Flight Control Mode

The mean HQR for the Hover Turn Bob-up with AFCS was 5.6, with pilots reporting a mixed rating between HQR 4 and HQR 7. A Cooper/Harper rating of HQR 5.6 translates to between HQR 5, moderately objectionable deficiencies, adequate performance requires considerable pilot compensation, and HQR 6, very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation. This is slightly less than a 1-point improvement over the HQR rating for this flight control mode using Contact Analog symbology.

Pilot comments: The most repeated pilot comments concerning the symbology and the flight control handling qualities were as follows:

- Five out of six pilots reported that altitude capture was difficult. Collective response was too sensitive. There was a tendency to overshoot the target altitude by a wide margin.
- Five out of six pilots commented that the rate-of-climb response to collective input was not linear, causing objectionable oscillations in the vertical axis. Altitude control was a high-workload task.
- Four of six pilots thought that heading control was precise and it was easy to achieve desirable standards.
- Two pilots commented that they could be aggressive with yaw because the target heading was in the FOV during the entire maneuver with the Compressed heading tape, thereby reducing workload.
- Four pilots complained they could not maintain hover position because of a lack of position-keeping symbology.

4.5 Pilot Performance Data Plots

Each pilot recorded 16 data flights (8 Contact Analog and 8 Compressed) for this maneuver. The total number of data runs for all 6 pilots was 96. Only selected data flights are presented in this section. The charts selected are representative of HQR ratings between 3 and 7 by different pilots. Charts of both Contact Analog and Compressed symbology in the VelStab and AFCS flight control modes are included. A complete set of data charts is available upon request.

4.5.1 Contact Analog, VelStab, Run 373

Run 373 data are representative of Pilot 5's performance during this maneuver. The pilot rated this maneuver HQR 4, minor deficiencies, desired standards, considerable pilot compensation. VelStab Position Hold ON was able to maintain aircraft position over the ground within desired standards of 6 ft horizontally from the start position. The pilot appears to have overshot altitude by 12 ft but recovered before engaging Altitude Hold. Desired standards of 5 ft over the target altitude of 60 ft were met. Heading control was nearly perfect, with a minor 1° overshoot.

4.5.2 Contact Analog, VelStab, Runs 166, 168, and 371

These runs are included to show that VelStab was not capable of holding position on every run. Adequate standard for position was ±10 ft. Positions were displaced by as much as 20 ft on these runs. Other runs showed similar numbers. Aggressiveness of the maneuver may possibly have been a determining factor concerning the ability of VelStab to maintain adequate position. Aggressiveness of flight control movement may saturate the ability of the flight control system to react to maintain position. Pilot wrist coupling in the SAC may cause pilots to inadvertently pull the aircraft out of position. The actual cause requires further investigation.

4.5.3 Contact Analog, AFCS, Run 404

The same pilot that flew Run 373 and rated it HQR 4 with VelStab rated this maneuver HQR 7 in the AFCS flight control mode. This rating translates to very objectionable but tolerable deficiencies requiring extensive pilot compensation. It is evident that maintaining a hover position without VelStab is difficult at best. The pilot drifted out of adequate standards by over 15 ft as the time for the maneuver expired. This clearly shows the effect of hand flying the aircraft without adequate position-keeping symbology. Difficulty in altitude control was evident during this run, with obvious vertical oscillations. The pilot was barely able to meet adequate altitude standards (8 ft lower than target 60 ft) as the 15-second time expired. Heading was initially overshot by 10° but recovered to desired standards within 2° of the target heading within the time standard.

4.5.4 Compressed, VelStab, Run 303

Run 303 represents typical performance by Pilot 4, who rated this maneuver HQR 3, some mildly unpleasant deficiencies, minimal pilot compensation required for desired performance. VelStab held hover position very nicely during the maneuver, meeting desired standards of less than a 6-ft drift. Altitude was managed nearly perfectly, with a very consistent rate of climb and no oscillations during level-off. Heading was managed perfectly, with no variance from the target heading. This maneuver was performed as perfectly as humanly possible and accurately reflects the HQR rating given by the pilot.

4.5.5 Compressed, AFCS, Run 312

Run 312 represents a difficult run for Pilot 4, who rated this maneuver HQR 4, minor deficiencies, requiring considerable pilot compensation. It is clear that adequate position standards could not be met without VelStab Position Hold. The pilot moved out of the starting position by as much as 35 ft. Altitude was overshot by 9 ft and then undershot by 9 ft, showing a clear difficulty in managing the vertical axis because of collective sensitivity issues. The pilot was within adequate altitude standards as time expired. Heading was managed perfectly with zero error from the target heading.

The Transient Turn maneuver is described in figure 27.

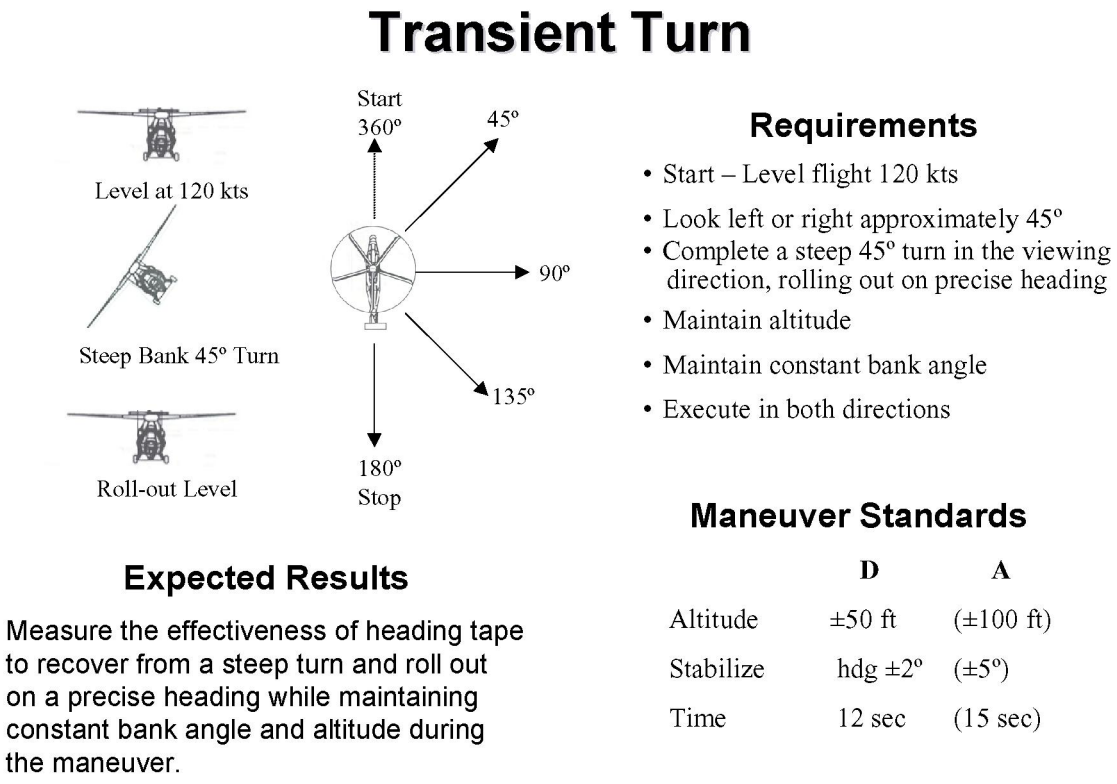

Figure 27. Transient Turn.

4.6 Transient Turn

4.6.1 Contact Analog Symbology – VelStab Flight Control Mode

The mean HQR for the Transient Turn maneuver with VelStab was 3.6, with 4 of 5 pilots rating the maneuver HQR 4. A Cooper/Harper rating of HQR 4 translates to minor deficiencies. Desired performance required considerable pilot compensation. This maneuver was an up-and-away maneuver that required different aircraft maneuvering skills and presented some different challenges to the symbology presentation when compared to the previous hover maneuvers. This maneuver required managing multiple axes (airspeed, pitch, angle of bank, and time) simultaneously with aggressive stick input. This maneuver was performed at altitude and cruise airspeed. As such, minimal visual ground cues were available, requiring the pilot to rely heavily on the symbology to meet task standards. This would be considered a high-gain task even under good visual conditions. Pilots seemed to perform well, as reflected by the HQR rating.

Pilot comments: The most repeated pilot comments concerning the symbology and the flight control handling qualities were as follows:

- Five out of six pilots reported difficulty in determining and achieving the desired angle of bank. Bank angle was not predictable. No precise bank-angle symbology cues were available.
- Five out of six pilots had a tendency to overshoot the intended bank angle.

- Four of six pilots could not read the heading tape during the turn because it moves too quickly. One reported that it was useful only during the last 15° of turn as the turn slowed. All used the digital heading as an analog reference, which is not optimal.
- Four pilots commented that during the turn, only a shortened heading tape was visible because it was driven into the upper corner of the display. The result was that the pilot saw less of the heading tape than was required for the maneuver. Pilots would like to see the target heading sooner to better predict turn roll-outs.
- Two pilots reportedly had to skew their head position to be able to view more of the heading tape.
- Two pilots thought the heading tape caused disorientation because of the shortened amount of tape in the FOV, the conflict of the heading tape with the horizon line, and the speed of heading tape movement. One had a tendency to look up at the heading tape, which he reported as too high in the HMD FOV.
- One pilot complained of no usable pitch or bank symbology; he also reported that the Earth-referenced heading tape could not be used as a precise bank indicator.

4.6.2 Contact Analog Symbology – AFCS Flight Control Mode

The mean HQR for the transient turn with AFCS was 5.0, with the majority of the pilots rating 4 or 5. HQR 5 translates to moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation. This is a 1.5-point decrease in handling qualities acceptability as compared to the same maneuver in the VelStab mode. Ratings went from minor deficiencies to moderately objectionable deficiencies requiring extensive pilot compensation.

Pilot comments: The most repeated pilot comments concerning the symbology and the flight control handling qualities are as follows:

- Five of five pilots reported they could not control altitude or airspeed precisely because of the absence of precise pitch attitude symbology, resulting in pitch oscillations.
- Two pilots thought they needed a pitch ladder for this maneuver.
- Three of five pilots commented that the heading tape is driven into the corner of the HMD FOV and shorted considerably. The small amount of visible heading tape is not sufficient to predict when to roll out of the turn. The target heading appears too quickly to react without overshoot.
- Two pilots reported a slight roll oscillation.
- Two pilots reported a tendency to overshoot altitude, and two reported a tendency to overshoot heading.
- One pilot reported the horizon line was not usable because it was out of the FOV. Another pilot commented that the Earth-referenced heading tape was not an adequate bank angle cue.
- One pilot reported the AFCS flight controls required less stick pressure in the turn to maintain angle of bank than VelStab.

4.6.3 Compressed Symbology – VelStab Flight Control Mode

The mean HQR for the transient turn with VelStab was 3.0 HQR, which translates to fair, some mildly unpleasant deficiencies, minimal pilot compensation required for desired performance. The Compressed symbology was rated only 0.6-point better than Contact Analog for this maneuver in the VelStab flight control mode, not a very significant difference. More pilots achieved desired performance on this maneuver than adequate.

Pilot comments: The most repeated pilot comments concerning the Compressed symbology and the VelStab flight control handling qualities were as follows:

- Three of five pilots reported that the compressed heading tape made heading management easier than Contact Analog because they could see the target heading at all times during the maneuver. This meant less pilot workload and made rolling out on the desired heading easier and more predictable.
- Several pilots commented on bank angle. One commented that no precise bank angle symbology is available. Another commented that aircraft control gets less predictable at bank angles of 45° or greater. A noticeable pitch oscillation occurs at 45° or greater angles of bank. Higher bank angles beyond 40° increase pilot workload and decrease accuracy. SAC stick forces are high, with high bank angles.
- One pilot commented that the compressed VSI symbology was easier to use and a better analog cue than the Contact Analog symbology.

4.6.4 Compressed Symbology – AFCS Flight Control Mode

The mean HQR for the transient turn with AFCS was 4.4. This translates to a rating slightly worse than minor deficiencies. Desired performance required considerable pilot compensation. This is only a 0.6-point improvement over the HQR rating for this flight control mode using Contact Analog symbology, not very significant.

Pilot comments: The most repeated pilot comments concerning the symbology and the flight control handling qualities were as follows:

- Four of five pilots reported a tendency to overshoot heading when bank angles approached 45° or greater. Two reported higher bank angles also caused altitude excursions. The more aggressive the bank angle the less precise the maneuver results.
- Two pilots commented that it was easy to achieve the desired heading with the compressed heading tape because the target heading was always visible during the turn.
- Three pilots reported a need for precise pitch and bank angle symbology.

4.7 Pilot Performance Data Plots

Each pilot recorded 16 data flights (8 Contact Analog and 8 Compressed), totaling 80 data runs for the 5 pilots who flew the Transient Turn maneuver. Pilot 1 did not fly this maneuver because of time constraints. Only selected data flights are presented in this section. The charts selected are representative of HQR ratings between 2 and 4 by different pilots. Charts of both Contact Analog

and Compressed symbology in the VelStab and AFCS flight control modes are included. A complete set of data charts is available upon request.

4.7.1 Contact Analog, VelStab, Run 509

Run 509 (Pilot 6) data are representative of pilot performance during this maneuver. The pilot rated this maneuver HQR 4, minor deficiencies, desired standards, considerable pilot compensation. VelStab Altitude Hold ON assisted the pilot with maintaining altitude and airspeed during this maneuver. Altitude Hold greatly assisted in maintaining the 1500-ft starting altitude within 5 ft during this aggressive maneuver. The graph clearly shows small altitude spikes of only 2 to 5 feet, commensurate with each roll-in and roll-out maneuver. Bank angles were very consistent at 30° to 32° in spite of the lack of precise bank angle symbology. This is the exact minimum bank angle required to meet the time standard. Heading roll-out was very precise at each of the 4 target headings, with no visible over- or undershoots. This is an example of a near-perfect maneuver.

4.7.2 Contact Analog, AFCS, Run 545

Run 545 was flown by the same pilot as Run 509 with the only difference being the flight mode. This pilot went from an HQR 4 with VelStab to an HQR 7 in the AFCS mode. Altitude control varied by 200 ft up and down, exceeding adequate standards by 100 ft. Banks angles were very inconsistent between 25° and 42°. Roll out to wings level was exceeded by 10° to 22°. Heading was relatively well controlled, with only one minor overshoot that was corrected. Bank angle and altitude control were the issues. These are both related to lack of adequate pitch and bank angle cues and are well documented in the comments section.

4.7.3 Compressed, VelStab, Run 705

This run was flown by Pilot 2, who gave the maneuver an HQR of 4, minor deficiencies, desired performance required considerable pilot compensation. This is typical of the 4 data runs he made in this flight mode. Altitude was maintained within 6 ft of the starting altitude. Again, VelStab Altitude Hold performed well, requiring little if any pilot input. Heading roll out was nearly perfect at each of the four target headings. The roll angles were very consistent at between 34° and 40°, perfect with respect to meeting the desired time. This performance is remarkable in that there is no precise bank angle symbology in the FOV and the lack of bank angle cues was heavily commented on.

4.7.4 Compressed, AFCS, Run 718

Pilot 2 flew the same maneuver as in Run 705 in the AFCS flight control mode, and he gave it an HQR of 6. This represents a significant decrease in performance from the experience in the VelStab mode. From the chart there appears to have been no effort to control altitude during the maneuver. It appears to have been left out of the cross check possibly because of high workload. The pilot gained approximately 200 ft during the maneuver, exceeding adequate performance by 100 ft. Heading was nearly perfect at each of the four stopping points. Bank angle rolling into the turn was very consistent at between 38° and 41°, about perfect to meet the time constraints. The pilot overshot the roll out three out of four times by approximately 5° each time.

The Traffic Pattern maneuver is discussed in figure 28.

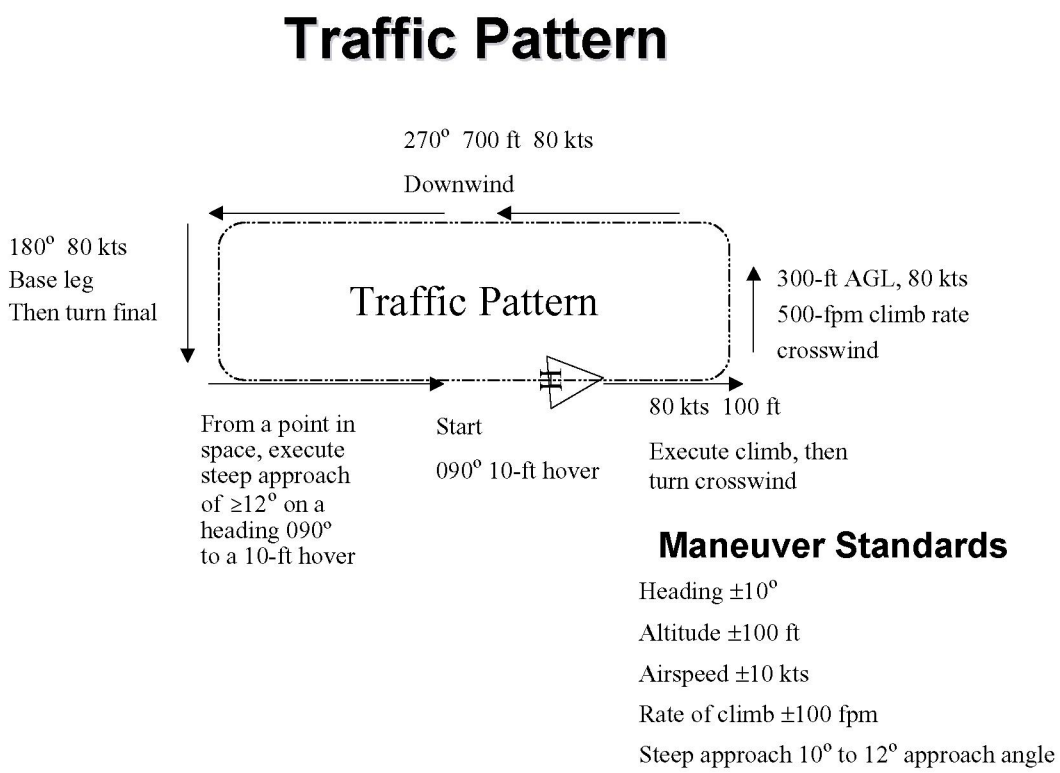

Figure 28. Traffic Pattern.

4.8 Traffic Pattern

4.8.1 Contact Analog Symbology – VelStab Flight Control Mode

The mean HQR for the Traffic Pattern maneuver with VelStab was 3.1, with a nearly consistent rating of HQR 3 by 5 of 6 pilots. HQR 3 translates to fair, some mildly unpleasant deficiencies, minimal pilot compensation required for desired performance. The mean HQR for the approach was 4.8, which translates to moderately objectionable deficiencies, adequate performance requires considerable pilot compensation.

This maneuver was an up-and-away maneuver that required different aircraft maneuvering skills and presented some different challenges to the symbology presentation when compared to the hover maneuvers. This maneuver required managing multiple axes (airspeed, pitch, angle of bank, rate of climb/descent, and rate of closure). Much of the maneuver was performed at altitude and cruise airspeed. As such, minimal visual ground cues were available, requiring the pilot to rely heavily on the symbology to meet task standards. The most challenging segment of this maneuver was the steep approach, where an aggressive and precise decelerative attitude had to be maintained along with a constant approach angle while looking down at the intended touchdown point. The handling qualities for the approach were rated separately from the Traffic Pattern.

Pilot comments: The most repeated pilot comments concerning the symbology and the flight control handling qualities were as follows:

- Three of six pilots commented that rate of climb was not predictable using the Contact Analog VSI. The collective sensitivity contributed to this problem.
- Three pilots reported that a lack of pitch cues made determination of a precise decelerative attitude on approach very difficult to manage.
- Three pilots commented that the iron wings and horizon line were driven off the top of the display by as little as an 8° approach angle.
- Two pilots reported the airspeed and rate of closure difficult to judge during the approach.
- One pilot reported the flightpath vector greatly assisted in maintaining approach angle.

4.8.2 Contact Analog Symbology – AFCS Flight Control Mode

The mean HQR for the traffic pattern with AFCS was 4.3, with half of the pilots rating HQR 5. HQR 4 translates to minor deficiencies, desired performance required considerable pilot compensation. The mean HQR for the approach was 4.8. Half of the pilots rated the maneuver HQR 5. This translates to moderately objectionable deficiencies, adequate performance requires considerable pilot compensation. The traffic pattern in the AFCS mode was rated a 1-point decrease in handling qualities acceptability when compared to the same maneuver in VelStab. The approach was rated the same in both flight control modes.

Pilot comments: The most repeated pilot comments concerning the symbology and the flight control handling qualities are as follows:

- Five of six pilots reported that airspeed and altitude were difficult to maintain because of a lack of pitch attitude cues during the traffic pattern. A more detailed attitude reference is needed.
- Three pilots commented that altitude maintenance was a high workload task because of the sensitivity of the collective and the VSI.
- Three pilots reported that rate of climb was not predictable or consistent with a constant power setting.
- Five of six pilots reported that determining and maintaining a steep approach angle was not predictable or repeatable. It was difficult to determine rate of closure.
- Six of six pilots reported the approach to be a high workload task.
- Three pilots reported that level attitude was difficult to maintain during the approach without a usable horizon line or aircraft reference. Both symbols were driven to the top of the display FOV and were unusable while looking at the intended landing point.
- Two pilots reported the flightpath vector to be helpful in maintaining the approach angle. All pilots used this cue during the approach. Only one pilot had difficulty managing it. One commented that the FPV disappears too soon during the approach as the aircraft slows.

4.8.3 Compressed Symbology – VelStab Flight Control Mode

The mean HQR for the Traffic Pattern with VelStab was 3.1. HQR 3.0 translates to fair, some mildly unpleasant deficiencies, minimal pilot compensation required for desired performance. The Compressed symbology was rated only 0.3-point better than Contact Analog for this maneuver, not a significant difference. More pilots achieved desired performance on this maneuver than adequate. The HQR for the approach was 4.5, which falls on the break line between minor and moderate deficiencies and between achieving desired and adequate standards. There was no significant difference between Compressed and Contact Analog symbology for this maneuver.

Pilot comments: The most repeated pilot comments concerning the Compressed symbology and the VelStab flight control handling qualities were as follows:

- Four pilots reported they liked the scaling of the Compressed VSI better than the Contact Analog scale and found it easier to use.
- One pilot commented it was difficult to find a collective setting for a constant rate of climb.
- Two pilots commented that the Compressed heading tape was easy to use because the target heading was in view at all times during the maneuver. This reduced workload and offered better predictability in managing heading.
- Four of six pilots reported they had difficulty in establishing the appropriate decelerative attitude and collective setting for initiating the approach. They over and undershot the approach angle.
- Two pilots reported that the steep approach involved high workload.

4.8.4 Compressed Symbology – AFCS Flight Control Mode

The mean HQR for the traffic pattern with AFCS was 4.4. The 4.4 HQR for the approach falls on the break line between minor and moderate deficiencies and between achieving desired and adequate standards. There was no significant difference between Compressed and Contact Analog symbology for this maneuver in this flight control mode. The HQR for the approach was 4.8, which translates to moderately objectionable deficiencies, adequate performance requires considerable pilot compensation. The rating is exactly the same as the rating given for Contact Analog symbology in this flight control mode.

Pilot comments: The most repeated pilot comments concerning the symbology and the flight control handling qualities were as follows:

- Two pilots commented on the need for a pitch ladder to manage attitude precisely during the cruise and turn portions of the traffic pattern, causing airspeed and altitude excursions.
- One pilot reported that heading was easy to manage.
- All six pilots reported that not having an adequate precise pitch cue made finding an appropriate decelerative attitude difficult during the approach.
- All six pilots reported that maintaining a constant approach angle involved high workload. They tended to over and under arc the approach angle.
- Three pilots commented that the FPV was a valuable cue during the approach in maintaining approach angle. One pilot had no experience with a FPV and had difficulty managing this symbology.

4.9 Pilot Performance Data Plots

Each pilot recorded 8 data flights (4 Contact Analog and 4 Compressed) for the Traffic Pattern maneuver. Only selected data flights are presented in this section. The charts selected are representative of HQR 3 ratings for the Traffic Pattern and HQR 5 for the approach flown by different pilots. Charts of both Contact Analog and Compressed symbology in the VelStab and AFCS flight control modes are included. A complete set of data charts is available upon request.

4.9.1 Contact Analog, VelStab, Run 65

Run 65 (Pilot 1) data are representative of pilot performance during this maneuver. The pilot rated this maneuver HQR 3, minor deficiencies, desired standards, considerable pilot compensation. Five out of 6 pilots rated this maneuver HQR 3. Most pilots achieved desired performance in all criteria. Heading control with VelStab Heading Hold was nearly perfect during this run. Airspeed showed a 1- to 2-knot oscillation during the cruise portion of the maneuver. It is not known whether this was pilot induced or a flight control oscillation. The average rate of climb was 507 fpm, which is very near the target of 500 fpm and within the desired 100-fpm criterion. Altitude was held nearly perfect with the assist of VelStab Altitude Hold during the down wind and base legs of the Traffic Pattern. Deceleration was rapid but consistent during the approach. The approach was steep and the approach angle was held consistently, with no apparent over or under arcing of the approach angle. This is a good example of how this maneuver was designed to be flown.

4.9.2 Contact Analog, AFCS, Run 62

This run was flown by the same pilot (Pilot 1) as the VelStab Run 65 but with quite different results. Pilot performance slipped from desirable to adequate, and the HQR 5 rating given by the pilot accurately reflects the difference in performance. Heading was managed without difficulty, and required headings were maintained within 1°. There were no apparent over- or undershoots or oscillations noted in the data. The target airspeed of 80 knots was noticeably difficult to maintain. The pilot showed continuous oscillations of between 10 and 20 knots. Adequate performance was ±10 knots. This may reflect the comments concerning a lack of usable attitude reference, which would affect airspeed and altitude control. Altitude control slipped from desirable with VelStab to barely adequate in the AFCS mode. Oscillations of 80 to 100 ft are evident during the entire cruise portion of the maneuver. The adequate performance goal was ±100 ft in altitude. The approach was moderately steep, and the approach angle was fairly consistent with only a slight under arc. Airspeed was bleed-off consistently except for two small perturbations near the bottom of the approach, showing some uncertainty concerning rate of closure with the touchdown point.

4.9.3 Compressed, VelStab, Run 425

This is a typical VelStab Traffic Pattern by this pilot. He rated this maneuver HQR 3 for the Traffic Pattern and HQR 4 for the approach. Heading was maintained nearly perfectly during the cross wind, down wind, and base legs of the Traffic Pattern. Some deviation and adjusting to line up with the touchdown point is evident in the last turn to final, with small oscillations noted on final approach. Airspeed was maintained within 2 knots of the assigned 80 knots, with one 8-knot deviation (gain) during the turn to final approach. This deviation was within desired standards and was corrected quickly. Rate of climb averaged over 800 fpm, exceeding adequate standards by 300 fpm. Airspeed deceleration during the approach was smooth and consistent. Altitude was maintained

to desired standards during the cruise portion of the Traffic Pattern, with a 50-ft overshoot turning to cross wind and another 50-ft overshoot when turning to final approach.

4.9.4 Compressed, AFCS, Run 449

The same pilot (Pilot 6) who flew Run 425 in VelStab flew this data run in the AFCS mode. This pilot rated the Traffic Pattern HQR 8 and rated the approach HQR 5. His heading management was nearly perfect during the cruise portion of the pattern. Airspeed showed an increased workload and a continuous oscillation of 3 to 9 knots. This may have been due to the lack of precise attitude reference symbology as reflected in the comments section. Altitude control was barely within adequate standards (±100 ft), with one oscillation that bumped 100 ft low. Small altitude oscillations are evident throughout the cruise portion of the Traffic Pattern. The deceleration entry for the final approach was not consistent. There were distinct perturbations at 59 knots and again at the bottom of the approach at 20 knots. The bump at 20 knots reflects terminating the approach with excessive airspeed over the landing point and then subsequently bleeding it off to a hover. The approach angle was moderately steep and fairly consistent with a slight tendency to under arc.

SECTION 5. HQR SUMMARY

5.1 Summary of Detailed Analysis

5.1.1 HQR Summary

Table 4 summarizes pilot HQRs for the four maneuvers broken down by flight control system and symbology type.

TABLE 4. HOVER TURN HQRs

Hover Turn								
Contact Analog								
Pilot	P1	P2	P3	P4	P5	P6	Mean	Mode
VelStab	5	3	4	3	3	4	3.6	3
AFCS	8	7	7	5	6	7	6.6	7
Compressed								
VelStab	5	3	5	3	2	3	3.5	3
AFCS	7	7	5	5	7	6	6.1	7

5.1.2 Contact Analog

The HQRs in VelStab were between HQR 3 and HQR 4, indicating minor deficiencies with between minimal and considerable pilot compensation required to achieve desired performance. Pilots predominantly achieved desired performance on this maneuver with an occasional adequate. In the AFCS mode, handling qualities were HQR 6.6, with half the pilots rating HQR 7. Performance slipped from desired to marginally adequate. Pilots reported major deficiencies, with extensive to maximum pilot compensation required. This is a twofold decrease in acceptability compared to the same maneuver in the VelStab mode.

5.1.3 Compressed Symbology

The HQRs in the VelStab flight control mode averaged 3.5, with half the pilots rating HQR 3. Pilots reported some mildly unpleasant deficiencies requiring minimal to considerable pilot compensation required to meet desired performance. Pilots predominantly achieved desired performance on this maneuver with an occasional adequate. The 3.5 rating is virtually the same (one-tenth of a point better) than the VelStab rating using Contact Analog symbology. The HQRs in the AFCS mode were much worse, averaging 6.1, with half the pilots rating HQR 7. Deficiencies were very objectionable, with major deficiencies reported. This is slightly less than a twofold decrease in acceptability as compared to the same symbology in the VelStab flight control mode. This is similar to the ratings for AFCS using the Contact Analog symbology. Although pilots had a more difficult time with this maneuver in AFCS vs. VelStab, the HQR rating differences between Contact Analog and Compressed symbology were not significantly different.

Table 5 summarizes Hover Turn Bop-up pilot HQRs.

TABLE 5. HOVER TURN BOB-UP HQRs

Hover Turn Bob-up								
Contact Analog								
Pilot	P1	P2	P3	P4	P5	P6	Mean	Mode
VelStab	5	7	7	3	4	6	5.3	7
AFCS	7	6	7	4	7	7	6.3	7
Compressed								
VelStab	4.5	7	5	3	3	4	4.4	3-4
AFCS	7	7	6	4	5	5	5.6	5-7

5.1.4 Contact Analog Symbology

The HQR average in VelStab was HQR 5.3, with a range of HQR from 3 to 7. This translates to moderate deficiencies, with only adequate performance requiring considerable pilot compensation. This maneuver was much more difficult than the Hover Turn, which had an average VelStab HQR of 3.6. HQRs in the AFCS mode averaged 6.3, with half the pilots rating HQR 7. This indicates marginally adequate performance with very objectionable and major deficiencies noted. Maximum pilot compensation was required. This is a 1-point decrease in acceptability as compared to the same maneuver in the VelStab mode. This maneuver was complex and required managing multiple axes (yaw, climb rate, position, time) simultaneously. Increased HQR ratings reflect the increased difficulty with the available flight controls and symbology.

5.1.5 Compressed Symbology

The average VelStab HQR was 4.4 with ratings ranging from HQR 3 to 7. HQR 4.4 translates to between HQR 4, minor deficiencies, desired performance, considerable pilot compensation, and HQR 5, moderately objectionable deficiencies, adequate performance, considerable pilot compensation. The Compressed symbology was rated a full HQR point better than Contact Analog for this maneuver in the VelStab flight control mode. The average HQR for the AFCS control mode was 5.6. Pilots reported moderate to very objectionable deficiencies requiring extensive pilot compensation. This is nearly a 1-point improvement over Contact Analog symbology in this mode.

Table 6 summarizes Transient Turn pilot HQRs.

TABLE 6. TRANSIENT TURN HQRs

Transient Turn								
Contact Analog								
Pilot	P1	P2	P3	P4	P5	P6	Mean	Mode
VelStab	N/A	4	4	4	2	4	3.6	4
AFCS	N/A	4	5	5	4	7	5.0	4-5
Compressed								
VelStab	N/A	4	2	3	3	3	3.0	3
AFCS	N/A	6	4	4	3	5	4.4	4

5.1.6 Contact Analog Symbology

The average HQR in VelStab was 3.6, with a predominant rating of HQR 4. Pilots reported minor deficiencies, with considerable pilot compensation required for desired performance. The mean HQR in AFCS was 5.0. Pilot performance slipped from desired to adequate. This is a 1.5-point decrease in handling qualities acceptability as compared to the same maneuver in the VelStab mode. Ratings went from minor deficiencies to moderately objectionable deficiencies requiring extensive pilot compensation. This maneuver was an up-and-away maneuver that required different aircraft maneuvering skills and presented some different challenges to the symbology presentation when compared to the previous hover maneuvers. This maneuver required managing multiple axes (airspeed, pitch, angle of bank, and time) simultaneously with aggressive stick input. This maneuver was performed at altitude and cruise airspeed. As such, minimal visual ground cues were available, requiring the pilot to rely heavily on the symbology to meet task standards. This would be considered a high-gain task even under good visual conditions. Pilots seemed to perform well, as reflected by the HQR rating.

5.1.7 Compressed Symbology

The mean HQR in VelStab was 3.0, with ratings ranging from HQR 2 to 4. HQR 4.4 translates to mildly unpleasant deficiencies with minimal pilot compensation required for desired performance. The Compressed symbology was rated a point better than Contact Analog for this maneuver. The average HQR in AFCS was 4.4. This translates to a rating slightly worse than HQR 4, minor deficiencies. Desired performance required considerable pilot compensation. This is only a 0.6-point improvement over the HQR rating for this flight control mode using Contact Analog symbology, not very significant.

Tables 7 and 8 summarize Traffic Pattern and Steep Approach pilot HQRs, respectively.

TABLE 7. TRAFFIC PATTERN HQRs

Traffic Pattern								
Contact Analog								
Pilot	P1	P2	P3	P4	P5	P6	Mean	Mode
VelStab	3	3	3	4	3	3	3.1	3
AFCS	5	5	4	4	3	5	4.3	5
Compressed								
VelStab	3	3	2	3	3	3	2.8	3
AFCS	4.5	4	3	4	5	4	4.5	4

TABLE 8. STEEP APPROACH HQRs

Steep Approach								
Contact Analog								
Pilot	P1	P2	P3	P4	P5	P6	Mean	Mode
VelStab	6	4	5	5	5	4	4.8	5
AFCS	4	6	5	5	5	4	4.8	5
Compressed								
VelStab	5	5	4	4	5	4	4.5	4-5
AFCS	5	5	5	4	5	5	4.8	5

5.1.8 Contact Analog Symbology

The mean HQR in VelStab was 3.1. Pilots reported some mildly unpleasant deficiencies in executing the Traffic Pattern, requiring minimal pilot compensation to achieve desired performance. The mean HQR for the approach was 4.8, which translates to moderately objectionable deficiencies, adequate performance requires considerable pilot compensation. The mean HQR for the traffic pattern in AFCS was 4.3, with half of the pilots rating HQR 5. HQR 4 translates to minor deficiencies, with considerable pilot compensation required for desired performance. The mean HQR for the approach was 4.8, with half of the pilots rating the maneuver HQR 5. Pilots reported moderately objectionable deficiencies, requiring considerable pilot compensation to achieve adequate performance. The traffic pattern in AFCS was rated a 1-point decrease in handling qualities acceptability as compared to the same maneuver in the VelStab mode. The approach was rated the same in both flight control modes.

5.1.9 Compressed Symbology

The mean HQR in VelStab was 2.8 for the Traffic Pattern, with ratings ranging from HQR 2 to 3. HQR 2.8 translates to mildly unpleasant deficiencies with minimal pilot compensation required for desired performance. The Compressed symbology was rated a point better than Contact Analog for the traffic pattern. The average HQR in AFCS was 4.5. This translates to a rating slightly worse than HQR 4, minor deficiencies. Desired performance required considerable pilot compensation. The HQRs for the Steep Approach were nearly the same for both flight control modes, with the mean for VelStab at 4.5 and 4.8 for AFCS. These scores translate to moderately objectionable deficiencies, adequate performance requires considerable pilot compensation.

SECTION 6. PILOT COMMENT SUMMARY

The most repeated comments for all maneuvers follow.

6.1 Contact Analog Heading Tape

Every pilot who participated in this simulation reported that the Contact Analog heading tape was unreadable during turns (hover and up-and-away) because it scrolls too quickly. The heading tape can be read only when the turn slows down. It is, therefore, not a usable analog cue. Pilots tended to compensate for the lack of an analog cue by using the digital heading as an analog indicator of where they were in a turn. Digital readouts were not intended to be used in this manner, and they tend to offer poor analog cues.

All pilots reported a tendency to overshoot the desired heading using the Contact Analog heading tape in both hover and up-and-away turning maneuvers.

Five of six pilots reported that the digital heading was not useful as an analog predictor because it scrolled too quickly. The digital heading was difficult to read during hover and up-and-away turns because of the scroll speed.

Many comments were received stating that the heading tape appears to move faster than the aircraft yaw rate, leading to mental confusion and disorientation. Heading-tape movement with head movement gives the feeling that aircraft yaw rates are greater than actual rates.

Two pilots commented they had a tendency to want to tilt their head back to see the heading tape because it is too high in the HMD FOV (this could lead to vertigo in a turn).

Pilots reported that they could not see enough of the Contact Analog heading tape in a turn to accurately predict when to roll out. More heading tape needs to be visible in order to provide more usable analog predictive cues.

Four of six pilots reported that during a cruise turn, only a very small portion of the heading tape was visible because the Earth-referenced tape was driven into the upper corner of the display. The result was that the pilot saw less of the heading tape than was required for cruise flight turns. The target roll-out heading was not visible soon enough to be a usable analog cue for predicting a precise turn roll-out. Two pilots reported the shortened tape, speed of movement, and conflict with the horizon line caused spatial disorientation.

Pilots reported repeatedly that combining head movement with aircraft yaw led to disorientation and distraction. Pilots complained of having to repeatedly look back over the nose of the aircraft to see the lubber line to capture aircraft heading. Excessive head movements during turns can lead to disorientation.

6.2 Compressed Heading Tape

All six pilots reported no problems in meeting desired standards in an aggressive Hover Turn using the Compressed heading tape. Heading was easy to manage during hovering and cruise flight turns. Pilots repeatedly commented they liked the Compressed heading tape because the target heading was visible during the entire maneuver, reducing workload and freeing cross-check time.

6.3 Horizon Line (Contact Analog)

Three pilots commented that the Contact Analog horizon line is driven to the top of the display and is unusable with as little as an 8° approach angle. The problem gets worse with steep approach angles.

All six pilots reported that the absence of a usable horizon line for a pitch cue made finding an appropriate decelerative attitude difficult during the Steep Approach.

Five of six pilots commented that airspeed and altitude were difficult to control because of the lack of precise pitch attitude cues during cruise flight. Placing the horizon line on the true horizon with the iron wings well above did not provide a precise enough attitude reference.

All six pilots also reported that maintaining a constant approach angle was a high-workload task with no usable symbology cues.

Half of the pilots reported that maintaining a level attitude during the Steep Approach was difficult because of the absence of a horizon line or aircraft symbol in the FOV. Both symbols were driven into the top of the HMD FOV and were unusable while looking down at the intended landing point during the approach.

All pilots reported that determining a steep approach angle was difficult and was neither predictable nor repeatable with the available Contact Analog symbology.

There were no positive comments relating to the Earth-referenced horizon line being fixed on the true horizon. This design feature resulted in many negative comments.

6.4 Vertical Axis Control

All pilots reported that the collective control is too sensitive to minor control input. The outcome of collective control input is not predictable. Aircraft vertical damping is too light. Rate of climb response to collective input was not linear, causing objectionable oscillations in the vertical axis in the AFCS mode. Pilots reported high workload.

Four of six pilots reported that VelStab Altitude Hold was slow to react when engaged during a vertical hovering climb. It did not capture the altitude quickly (aircraft floated upward after trigger release), causing overshoot. Leveling off at a target altitude was not predictable.

All pilots reported the breakaway force in the vertical axis of SAC was excessive. Most pilots did not use this feature because of the excessive force required.

6.5 Absence of Hover Position Symbology

All six pilots reported a need for precise hover-position symbology. The velocity vector and acceleration cues do not provide sufficient cues for maintaining a precise hover position in the AFCS mode.

6.6 Absence of Angle-of-Bank Cues

All six pilots reported difficulty in determining and achieving the desired angle of bank. Bank angle was not predictable. No precise angle-of-bank symbology cues were displayed on the HMD. This caused five out of six pilots to report a tendency to overshoot the desired angle of bank.

Pilots reported that the Earth-referenced heading tape is not adequate for use as a precise bank angle cue.

6.7 Rate of Climb (Contact Analog)

Three of six pilots reported that rate of climb was not predictable using the Contact Analog VSI. This VSI does not provide good predictive analog cues. Collective sensitivity may have contributed to this comment.

6.8 Rate of Climb (Compressed)

Four of six pilots reported they liked the scaling of the compressed VSI better than the Contact Analog VSI and found it a more predictable analog cue and easier to use.

6.9 Flightpath Vector

Pilots repeatedly commented on how useful the FPV was in executing the steep approach.

6.10 Recommendations for Further Research

Further research should be conducted where HQR ratings indicate a need for improvement. The areas requiring attention are those where the symbology implementation, the flight control system, or a combination of both caused workload to reach an objectionable level where adequate performance was either difficult to achieve or unachievable.

Symbology that received negative comments by the majority of pilots should also be examined. These were listed previously in the summary of pilot comments. Additional simulation trials should be considered to address these issues.

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APPENDIX A: PILOT HANDLING QUALITIES RATING COMMENTS

HOVER TURN

Pilot 1: – Task: Hover Turn **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards)	Did not lead the turn rollout enough. Amount of lead required to stop turn difficult to predict. Could not control position. Altitude easy with VelStab.
2. Describe how aggressive and how precise you could perform the task.	Had to lead turn rollout by 30°. Once this was determined was able to be more aggressive.
3. Describe predictability of initial aircraft response (controller force characteristics, etc.).	Stopping turn rate not predictable ±10°.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to over/undershoot turn rollout.
5. Describe strategy for performing the task.	Looked in direction of turn to find a lead-in heading to stop at. Used digital heading once turn slowed.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Could not use heading tape until turn slowed down. Able to use digital heading when turn slowed down.

Pilot 2: – Task: Hover Turn **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 3** – Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Fair. Not that difficult but had to work at it. Large scale heading tape was good for this type of aircraft pointing maneuver. The problem is you only see a small amount of the scale because it is not compressed.
2. Describe how aggressive and how precise you could perform the task.	Can be aggressive with VelStab because you don't manage position or altitude.
3. Describe predictability of initial aircraft response.	Large scale heading tape is easy to overrun because it moves so quickly and you see very little of the scale. Predictability was good however. With experience you could manage this.
4. Describe any objectionable oscillations or tendency to overshoot.	Slight tendency to overshoot heading but did not exceed desirable standards.
5. Describe strategy for performing the task.	Started looking for the target heading at 90° off axis. Slowed turn at 20° off axis prior to target heading then roll out. Used heading tape as an analog indication the last 20° of turn.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape is helpful during the task. However, the heading tape location high in the HMD visual field made it more difficult to read and use. Perception of turn rate can be confusing because heading tape moves faster than yaw rate. Shortened heading tape in top corner of the display is problematic. There is no symbology available for use as a ground position reference.

Pilot 3: – Task: Hover Turn **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	This maneuver is easy with altitude hold ON.
2. Describe how aggressive and how precise you could perform the task.	Moderately aggressive.
3. Describe predictability of initial aircraft response.	Experienced some cross coupling effects in wrist using SAC. Yaw rate roll out point a little hard to predict.
4. Describe any objectionable oscillations or tendency to overshoot.	Minor overshoot problem. Some fine tuning required to meet desired standards.
5. Describe strategy for performing the task.	Ramped up to high yaw rate then slowed yaw starting at 160°. Scan pattern was heading, altitude, and position.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading, RADALT, velocity vector, acceleration cue. Objectionable symbology – Could not read heading tape during the turn. Tape moved too fast. Had to rely on digital heading, which does not provide analog cues. Missing was a hover position box.

Pilot 4: – Task: Hover Turn **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 3 –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Able to meet desired criteria without much problem.
2. Describe how aggressive and how precise you could perform the task.	Had to be relatively aggressive to meet time requirements. Able to precisely stop on heading.
3. Describe predictability of initial aircraft response.	Predictability of aircraft response was predictable. Control input and response was predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	No objectionable oscillation or tendency to overshoot. Minimal drift. VelStab held position fairly well. Almost no altitude correction required with altitude hold on.
5. Describe strategy for performing the task.	Held fast turn rate until 10-15° before target heading then put in aggressive input to stop and made minor final adjustments. Paid little attention to altitude or position.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape mainly.

Pilot 5: – Task: Hover Turn **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 3 –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Easy to meet desired standards but difficult to determine yaw rate and distance from target heading with the uncompressed heading tape.
2. Describe how aggressive and how precise you could perform the task.	Difficult to determine yaw rate of turn. VelStab takes care of altitude and position. Difficult to determine where you are in the turn. Rely on outside scene to get a predictable roll out on heading.
3. Describe predictability of initial aircraft response.	Not predictable. No way to determine repeatedly what SAC force is required to obtain a desired rate. Cannot see target heading and current heading at the same time. Difficult to anticipate when desired heading will come into view.
4. Describe any objectionable oscillations or tendency to overshoot.	The faster the yaw rate the greater the tendency to overshoot the target heading. With the target heading not in the FOV all the time you spend more time cross checking heading which detracts from other cross check elements.
5. Describe strategy for performing the task.	Used digital readout to determine heading.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Cannot read heading tape during turn. Must use digital heading which is difficult to read during a high speed turn and difficult to uses as an analog scale to anticipate roll out. Cannot see enough of heading tape to predict when to roll out.

Pilot 6: – Task: Hover Turn **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Met desired standards.
2. Describe how aggressive and how precise you could perform the task.	Aggressive and precise. Heading precision was good. VelStab took care of everything else.
3. Describe predictability of initial aircraft response.	Predictable. Easy to stop. Easy to reverse direction.
4. Describe any objectionable oscillations or tendency to overshoot.	The tendency to overshoot heading was the result of the heading tape moving too fast.
5. Describe strategy for performing the task.	Slowed turn down near the roll out target heading. Got the heading in view and followed it around over the nose. Got the lubber line in view and matched the heading with the lubber line.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Used heading tape, velocity vector, RADALT. Did not look at torque. Heading tape moves to fast to be usable in a quick turn. It is only usable as an analog cue when the A/C turn rate slows down. Heading tape moving with head movement gives the feeling the aircraft is moving when it is not. Do not like the heading tape earth referenced in roll feature. Disorienting.

Pilot 1: – Task: Hover Turn **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 8 –** Major deficiencies. Considerable pilot compensation is required for control.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Not able to achieve adequate performance concerning A/C position. No symbology cues available for position maintenance. Vertical damping difficult to predict.
2. Describe how aggressive and how precise you could perform the task.	Issues with A/C vertical damping. Aggressiveness results in objectionable oscillation and altitude overshoot.
3. Describe predictability of initial aircraft response.	Difficult to predict aircraft response in altitude.
4. Describe any objectionable oscillations or tendency to overshoot.	Objectionable oscillations in vertical axis due to aircraft damping issues. Tendency to overshoot target altitude.
5. Describe strategy for performing the task.	Turn head is direction of turn. Attempt to maintain position and position until close to desired heading then fine tune.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape and digital heading.

Pilot 2: – Task: Hover Turn **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Not able to meet adequate standards for altitude or position.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive due to difficulty in maintaining parameters. Heavy workload. Tentative heading control.
3. Describe predictability of initial aircraft response.	Predictability was good in spite of the workload.
4. Describe any objectionable oscillations or tendency to overshoot.	Overshot all parameters. Once past 90° in the turn altitude became difficult to control.
5. Describe strategy for performing the task.	Tentative approach to heading control. Tried not to move the collective. Once past 90° in the turn altitude became difficult to control.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Could not use the hover symbology to maintain position. Altitude predictor gave a sense of rate.

Pilot 3 : – Task: Hover Turn **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Was not able to maintain altitude without VelStab. Was not able to correlate the velocity vector and acceleration cue with the outside scene and could not maintain position.
2. Describe how aggressive and how precise you could perform the task.	Could not be aggressive. Small precise collective movements are difficult to make. Workload very high. Could not manage altitude, position and heading all at once. Not enough time to perform the task without being aggressive.
3. Describe predictability of initial aircraft response.	Collective inputs results were not predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	Was constantly chasing the symbology. Felt reactive rather than proactive. Behind on symbology cross check.
5. Describe strategy for performing the task.	None offered.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, RADALT, velocity vector and acceleration cue. Missing hover position cue.

Pilot 4 : – Task: Hover Turn **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Heading was desired. Altitude was generally adequate. Could not hold position within standards.
2. Describe how aggressive and how precise you could perform the task.	Had to be relatively aggressive in the turn to meet the time standard. Had to pay very close attention to altitude and collective management during rapid turns.
3. Describe predictability of initial aircraft response.	Yaw response was good. Pitch was easy to maintain. Controlling altitude with collective was not predictable. The output does not correlate with what is expected from the collective input. Light control damping.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to overshoot altitude both up and down. Response from up and down collective was not uniform or predictable. Without problem was made more relevant due to lack of proprioceptive cues. You don't get enough information fast enough to control altitude. There was no tendency to overshoot yaw.
5. Describe strategy for performing the task.	None mentioned.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Need cues to maintain position over the ground. You cannot tell drift or drift rate.

Pilot 5: – Task: Hover Turn **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 6 –** Very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Position maintenance not possible with available symbology.
2. Describe how aggressive and how precise you could perform the task.	Speed affects precision. The faster and more aggressive you try to be the less precise your results.
3. Describe predictability of initial aircraft response.	No sense of aircraft rate of turn. Heading tape moves too fast to be a cue.
4. Describe any objectionable oscillations or tendency to overshoot.	Difficult to maintain altitude. Collective input and output are not symmetrical. Different sensitivity and reaction with increase vs. decreasing collective. This causes a tendency to over/undershoot altitude.
5. Describe strategy for performing the task.	Strategy was to ensure VSI was zero prior to initiating turn. Once in the turn immediately focused on velocity vector to minimize drift then continued to crosscheck other indicators.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Crosscheck would tend to break down due to difficulty in figuring out what the current heading was. Heading tape unreadable during turn. Digital heading was not designed as an analog scale. Most of the available cross check time was used to manage heading which cause a loss of preciseness in other axis.

Pilot 6: – Task: Hover Turn **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Met desired or adequate except in altitude. Heading moves too fast to read and use information. This resulted in using a lot of available cross check time being devoted to only one axis.
2. Describe how aggressive and how precise you could perform the task.	Can be aggressive in yaw but not in altitude.
3. Describe predictability of initial aircraft response.	Collective was unpredictable. Yaw was consistent and predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	Tended to overshoot heading because it moved so fast it was unreadable. Overshot altitude because the collective is too sensitive.
5. Describe strategy for performing the task.	Used a strategy of tightening the collective friction and not moving the collective. The strategy did not work however.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, RADALT, velocity vector, acceleration cue. Collective too sensitive and unpredictable. Heading tape moved too fast to be readable during a rapid turn. Earth referenced heading tape feature causes disorientation and induces unnecessary input to aircraft controls.

Pilot 1: – Task: Hover Turn **Symbology: Compressed**	**Flight Control System: VelStab** **HQR Rating: 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Could not hold hover position to meet standard. No symbology cues available for position maintenance. No problem with altitude or heading.
2. Describe how aggressive and how precise you could perform the task.	Fan Tail effectiveness limits aggressiveness.
3. Describe predictability of initial aircraft response.	Good predictability. The only input required was yaw control. Good response with full control input.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to overshoot heading due to fast yaw rate.
5. Describe strategy for performing the task.	Used heading tape almost entirely. Used large yaw input. Attempted to lead the turn. Errors were based on fast rate of turn.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Watched velocity vector and acceleration cue.

Pilot 2: – Task: Hover Turn **Symbology: Compressed**	**Flight Control System: VelStab** **HQR Rating: 3 –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Attitude and heading management are not an issue. The breakout forces on the SAC are very high. This results in an advantage to turning left. Highly stabilized system. Met desired/adequate performance.
2. Describe how aggressive and how precise you could perform the task.	Aggressiveness causes overshoot in heading.
3. Describe predictability of initial aircraft response.	Not predictable when attempting to use acceleration cue to maintain position. When the cue goes to the lower left and you attempt to correct it make the drift worse. Predictability also poor due to the great amount of control force required to get very little A/C response.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to overshoot heading turning to the right due to high SAC forces.
5. Describe strategy for performing the task.	Attempted to find roll out heading by looking in direction of turn then lead the roll out using digital heading. Let VelStab manage most of the parameters.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape. Velocity vector and acceleration cue were of little use in maintaining position. Position dots are a poor cue. No symbology missing from the display.

Pilot 3: – Task: Hover Turn **Symbology: Compressed**	**Flight Control System: VelStab** **HQR Rating: 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Easy to achieve desired standards for Heading due to compressed scale. Not possible to maintain position over the ground due to lack of station keeping symbology cues.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive or precise.
3. Describe predictability of initial aircraft response.	Hover cues are not predictable. Velocity vector and acceleration cues go in opposite directions.
4. Describe any objectionable oscillations or tendency to overshoot.	Overshot attempts to maintain position.
5. Describe strategy for performing the task.	Focused on position maintenance and time maintenance. Did not have time left over to attend to heading.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Need position keeping symbology to meet adequate standards.

Pilot 4: – Task: Hover Turn **Symbology: Compressed**	**Flight Control System: VelStab** **HQR Rating: 3 –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Was able to meet desired standards in all areas.
2. Describe how aggressive and how precise you could perform the task.	Moderately aggressive but precise.
3. Describe predictability of initial aircraft response.	Cyclic response was as expected. Yaw rate was predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	None.
5. Describe strategy for performing the task.	Used heading tape, altitude position and torque without paying much attention to the outside scene. Really concentrated on rate of turn to make the desired time. Led the yaw turn roll out by 4-5°.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Symbology was very useful. Like the compressed heading tape because you could see the entire turn from beginning to end.

Pilot 5: – Task: Hover Turn **Symbology: Compressed**	**Flight Control System: VelStab** **HQR Rating: 2 –** Good – Negligible deficiencies. Pilot compensation not a factor for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Met desired performance. Only had to worry about turn rate since VelStab held altitude and position.
2. Describe how aggressive and how precise you could perform the task.	Highly aggressive and yet was able to roll out on target heading accurately.
3. Describe predictability of initial aircraft response.	No way to predict the amount of force required to achieve desired turn rate.
4. Describe any objectionable oscillations or tendency to overshoot.	There isn't a clear-cut way to nail the desired heading. You get some under and overshoot then adjust to standard.
5. Describe strategy for performing the task.	Keyed on heading tape and tried to get my head back forward to determine turn rate.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Used heading tape almost entirely.

Pilot 6: – Task: Hover Turn **Symbology: Compressed**	**Flight Control System: VelStab** **HQR Rating: 3 –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Met desired standards.
2. Describe how aggressive and how precise you could perform the task.	Was able to be aggressive with the maneuver because VelStab managed altitude and position. Could concentrate on rates and accuracy.
3. Describe predictability of initial aircraft response.	Predictable A/C response. Seat shaker and engine noise helped.
4. Describe any objectionable oscillations or tendency to overshoot.	No objectionable oscillations. Slight tendency to overshoot heading.
5. Describe strategy for performing the task.	Spend little time cross checking altitude and position which feed me up to focus on heading accuracy.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading was the primary symbology used.

Pilot 1: – Task: Hover Turn **Symbology: Compressed**	**Flight Control System: AFCS** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Position maintenance cues were not provided. Cannot maintain position over ground.
2. Describe how aggressive and how precise you could perform the task.	Not able to complete maneuver in desired time. The only altitude cue was RADALT. Rate of climb and heading cues were sufficient for adequate performance. Was not able to roll out on exact heading. Requires a lot of pilot attention.
3. Describe predictability of initial aircraft response.	Was in complete control throughout the maneuver.
4. Describe any objectionable oscillations or tendency to overshoot.	Could not maintain position. SAC mechanization had some affect on this.
5. Describe strategy for performing the task.	No comment provided.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading, RADALT and ROC symbology.

Pilot 2: – Task: Hover Turn **Symbology: Compressed**	**Flight Control System: AFCS** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Altitude was difficult to maintain. The best way to handle it was to not move the collective. Turning at a slower rate also helps.
2. Describe how aggressive and how precise you could perform the task.	Could not do anything aggressive with this task. The workload of trying to maintain position and heading was a full workload.
3. Describe predictability of initial aircraft response.	Not predictable when attempting to use the acceleration cue and velocity vector to maintain position.
4. Describe any objectionable oscillations or tendency to overshoot.	Velocity vector and acceleration cues tend to be difficult to control when trying to maintain hover position.
5. Describe strategy for performing the task.	None mentioned.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Symbology was baffling. Could not use the velocity vector and acceleration cue to maintain position. Logical inputs based on symbol position seemed to give the opposite reaction to what one would expect.

Pilot 3: – Task: Hover Turn **Symbology: Compressed**	**Flight Control System: AFCS** **HQR Rating: 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Maintaining altitude was extremely difficult. Constant, small inputs were required. Very high workload. Lightly damped control system. Very small cyclic inputs required for position maintenance. Compressed heading tape made heading management easy.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive. Heading was not the issue. Aggressiveness was dictated by difficulty in position maintenance.
3. Describe predictability of initial aircraft response.	Velocity vector and acceleration cue was not predictable. Velocity vector left front and acceleration cue right rear seemed opposite of what it should be and was confusing.
4. Describe any objectionable oscillations or tendency to overshoot.	Rolling out of a right turn induced an objectionable tendency for the nose to pitch up and roll right which causes a climb when you attempt to stop the hover turn. Wrist coupling on the SAC may be the cause.
5. Describe strategy for performing the task.	Symbology was very helpful. Strategy was to manage heading, position and altitude with the greatest focus on altitude.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Velocity vector and acceleration cues seem to move opposite of what was expected. Need a hover box for position maintenance.

Pilot 4: – Task: Hover Turn **Symbology: Compressed**	**Flight Control System: AFCS** **HQR Rating: 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Able to meet desired in heading. Was adequate most of the time in altitude but slipped below adequate on occasion.
2. Describe how aggressive and how precise you could perform the task.	Could not be aggressive and still maintain altitude and position.
3. Describe predictability of initial aircraft response.	Yaw and turn rate were as expected. The compressed heading tape gives enough rate information that it made achieving heading a lot less workload. A/C response was not predictable in altitude. Had to chase the VSI.
4. Describe any objectionable oscillations or tendency to overshoot.	Altitude overshoot was due to the VSI symbology not giving a useable analog cue. Collective response was difficult to predict.
5. Describe strategy for performing the task.	None given.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Would prefer a different VSI symbology design and a more predictable collective response for controlling altitude.

Pilot 5: – Task: Hover Turn **Symbology: Compressed**	**Flight Control System: AFCS** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Easy to attain desired in heading. The problem was managing altitude with a sensitive collective while holding position. Was not able to maintain position or altitude. Got some acceleration as the turn was initiated. Position error management was high workload task.
2. Describe how aggressive and how precise you could perform the task.	Power input results are not predictable. Could not predict the appropriate control positions to maintain altitude throughout the maneuver.
3. Describe predictability of initial aircraft response.	Collective response was not predictable. Difficult to control altitude precisely. Very sensitive to small input.
4. Describe any objectionable oscillations or tendency to overshoot.	Objectionable oscillation in altitude that finds its way into other axis. Crosscheck breaks down under workload.
5. Describe strategy for performing the task.	Start the yaw rate going then work to manage altitude and position.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, RADALT, velocity vector, acceleration cue. Liked the VSI symbology better than Contact Analog.

Pilot 6: – Task: Hover Turn **Symbology: Compressed**	**Flight Control System: AFCS** **HQR Rating: 6 –** Very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Very difficult to meet adequate standards in altitude and position. Cross check was difficult. Heading was not a problem.
2. Describe how aggressive and how precise you could perform the task.	Not as aggressive as I would like to be. Had to slow down to meet maneuver criteria other than time. Could not be precise in altitude. Collective was too sensitive.
3. Describe predictability of initial aircraft response.	Collective response was not predictable. The collective input/output is too sensitive. Small changes in collective position caused large changes in vertical velocity.
4. Describe any objectionable oscillations or tendency to overshoot.	There were oscillations caused by having to chase altitude due to collective sensitivity. Altitude seemed to change faster than the VSI would predict.
5. Describe strategy for performing the task.	Initiated the turn then checked altitude for small adjustments then cross check heading again. This left little time to tend to altitude excursions or position.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, RADALT, VSI. Nothing to add.

HOVER TURN BOB-UP

Pilot 1: – Task: Bobup **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	"Altitude Hold" slow – not adequate. Break away forces on vertical axis of sidearm controller excessive. Altitude hold did not capture as quickly as would have liked. Difficult to hold aircraft position – no symbology cues. Easy to capture heading – predictability in yaw good. Workload in vertical axis difficult to manage. Rate of climb difficult to set precisely. Having to turn head to direction of turn and not having an A/C reference and making yaw motion at same time made the task more difficult. Canopy rails may have helped for orientation.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive due to SAC forces required. Heading was precise. Heading moved slowly enough to capture within 10°. Most of the workload was in the vertical axis. No workload in longitudinal or lateral axis. VelStab held position.
3. Describe predictability of initial aircraft response.	Predictability in yaw good. Predictability in rate of climb and stopping at appropriate altitude difficult and added workload. Predictability of onset of rate of climb not very good. Had to pull large force on SAC resulting in late response for ROC (2 sec).
4. Describe any objectionable oscillations or tendency to overshoot.	Large forces on Side Arm Controller (SAC) vertical axis caused tendency to under and overshoot altitude. Took 2 seconds for rate of climb to ramp up. This is excessive. Some overshoot in altitude. This was due to the capture of altitude by VelStab not being adequate.
5. Describe strategy for performing the task.	Pull up on SAC then start yaw motion, stabilize heading, wait on altitude, and stabilize altitude.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Combination of RAD ALT and heading tape and digital heading indication. The RAD ALT indications gave ample cueing to stop climb but altitude hold had overshoot and didn't capture as would have expected. Not possible to ascertain the heading from the heading tape but the digital readout was useable.

Pilot 2: – Task: Bob-up **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Controllability was satisfactory to adequate. Task requires delicate touch on the controls. Performed better to the left than right. going to the right. Altitude overshoots were common. Time was desired. Mixed results – about half adequate and about 40% desired.
2. Describe how aggressive and how precise you could perform the task.	Cannot be aggressive at all. No sense of precision. You game how to get the aircraft to coast into the desired parameters which is not likely to have a predictable outcome.
3. Describe predictability of initial aircraft response.	Don't have a sense of precision. Coasting in to meet parameters. Does not have a predictable outcome. Initial response is always in the right direction however.
4. Describe any objectionable oscillations or tendency to overshoot.	Oscillation in heading of about 5°. The altitude doesn't oscillate.
5. Describe strategy for performing the task.	Managed altitude first because it's the most difficult parameter to control. Cross check the heading a couple of times. Try to nail altitude then heading.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, RADALT, ROC symbology. There is a harmony mismatch between watching the altitude tape which moves at one rate and the heading tape that moves at a different rate. This rate differential makes it more difficult to cross check between the two. The RAD ALT thermometer is the most important thing – the heading tape is next and with VelStab on. The altitude loop performance is complicated by the mechanization of the collective.

Pilot 3: – Task: Bob-up **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Could not meet standards. Tried without success to use the VSI to assist in leveling off. Collective was lightly damped which required a lot of mental attention to deal with in attempting to level at desired altitude. Position maintenance was very difficult. Heading maintenance was relatively easy. Vertical axis was a high workload task and drove the time component.
2. Describe how aggressive and how precise you could perform the task.	Not able to be aggressive. Could only manage one axis at a time.
3. Describe predictability of initial aircraft response.	Collective input results were not predictable due to light damping. Would still be climbing with only 80% torque. No idea how to control drift. No position keeping symbology available. Heading maintenance was easy to control.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to overshoot the vertical axis. Could not predict what outcome collective inputs would have. Time available for the maneuver was consumed by attempting to hit the target altitude. Tendency to over control the collective inputs.
5. Describe strategy for performing the task.	The strategy was to control heading, altitude, and position in that order. Controlled one axis at a time.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, VSI, RADALT, velocity vector and acceleration cue. Need hover position box symbology. VSI was too sensitive for a lightly damped collective. Heading tape useless during turn because it moved to fast to be readable.

Pilot 4: – Task: Bob-up **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 3 –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Maneuver was relatively easy to achieve desired except on timing.
2. Describe how aggressive and how precise you could perform the task.	Used the vertical axis on the SAC and was able to meet desired altitude standards without much problem. You could be fairly precise with the assistance of VelStab.
3. Describe predictability of initial aircraft response.	A/C responded as expected in altitude and turn rate.
4. Describe any objectionable oscillations or tendency to overshoot.	No objectionable tendency to overshoot.
5. Describe strategy for performing the task.	Used outside cues to help with position. Used SAC for altitude and yaw. Started looking for target heading after 60° of turn.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Used digital heading for turn and RADALT.

Pilot 5: – Task: Bob-up **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	You can't look forward and hope to attain the heading that you are looking for. You had to go and find the heading and follow it around to the nose of the aircraft. This led to some disorienting feeling which causes distraction from other keys. This was difficult and caused moderate/high workload.
2. Describe how aggressive and how precise you could perform the task.	The more aggressive you performed the task the less precise you could be. The faster the tape moved the more difficult it was to roll out on a particular heading or to capture a particular altitude and maintain position.
3. Describe predictability of initial aircraft response.	Not predictable. Difficult to predict roll out on the target heading with fast yaw rates. The inability to keep your head focused in one particular axis and keep it still degraded form your ability to predict rate of A/C movement. If you keep your head forward you can loose track of the heading because tape is moving to quickly. If you capture a heading you are forced to move your head with the heading around so rate becomes a little more difficult to predict.
4. Describe any objectionable oscillations or tendency to overshoot.	Didn't notice any objectionable oscillations or tendency to overshoot except for altitude. This may be caused by a lack of proprioceptive cues.
5. Describe strategy for performing the task.	Attempted to grab it with the eyes and move it around to the forward of the aircraft and not allow the nose of the aircraft and the iron wings to come in too quickly to where you'd overshoot the heading.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Concentrated too much on the heading tape. Afraid of losing visual contact with the target heading. Lost track of altitude and the rate of climb to the target altitude. This was an objectionable characteristic of the heading tape presentation. No symbology missing.

Pilot 6: – Task: Bob-up **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 6 –** Very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Barely achieved adequate standards. Heading was confusing. Had to keep head looking over the nose to keep spatial orientation.
2. Describe how aggressive and how precise you could perform the task.	Aggressive enough to make the time requirement but not very precise.
3. Describe predictability of initial aircraft response.	Predictable in yaw but not in heave. Could not achieve repeatable altitude control.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to overshoot altitude. Collective sensitive.
5. Describe strategy for performing the task.	Strategy was to start the maneuver looking in the direction of the turn then quickly look over the nose to maintain spatial orientation.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Digital numbers move too fast to be useable. When you look off axis you lose the lubber line. Moving the head was mistaken for control input.

Pilot 1: – Task: Bob-up **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Heading capture OK. Tendency to PIO with collective. Too much delay in A/C response in vertical axis.
2. Describe how aggressive and how precise you could perform the task.	Not predictable enough to be very aggressive due to PIO in altitude.
3. Describe predictability of initial aircraft response.	Too much delay in A/C response to collective changes which produced PIO tendency.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to overshoot altitude due to collective response and PIO. Not able to use the predictor. No cues for maintaining position over ground
5. Describe strategy for performing the task.	Started turn and then altitude – complete turn before desired heading then concentrated on altitude
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Could not use the RADALT predictor for some reason. No cues for maintaining position over the ground. Turn was slow enough that heading tape and digital heading could be used. Did not use RADALT. Used outside cues to stop vertical motion.

Pilot 2: – Task: Bob-up **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 6 –** Very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	A/C was controllable. Heading roll out was good with time and altitude only adequate performance. Quite challenging but not that much worse than VelStab. Used just enough collective to give 200- to 400-fpm climb rate. Meeting altitude target very difficult. Timing is adequate all the time.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive. Precision is a matter of luck. The outcome is not predictable. Precision is more a matter of luck than it is skill. The predictability and consistency of the outcome is very ragged.
3. Describe predictability of initial aircraft response.	Large tendency to overshoot altitude. Heading was easier to manage but still overshot.
4. Describe any objectionable oscillations or tendency to overshoot.	Large tendency to overshoot altitude. Heading was easier to manage but still overshot because it's going so quickly.
5. Describe strategy for performing the task.	Altitude control was primary to a successful outcome. Get that under control then manage heading leading roll out by 20°. Heading is a matter of just putting an input in and gauging the rate you have and letting that percolate while you tend to the altitude tape.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	The VSI is most significant followed by altitude followed by heading. Occasionally I reverse the sense between velocity cues and acceleration and drifted out of position.

Pilot 3: – Task: Bob-up **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Could not meet standards. Tried without success to use the VSI to assist in leveling off. Collective was lightly damped which required a lot of mental attention to deal with in attempting to level at desired altitude. Position maintenance was very difficult. Heading maintenance was relatively easy. Vertical axis was a high workload task and drove the time component.
2. Describe how aggressive and how precise you could perform the task.	Not able to be aggressive. Could only manage one axis at a time.
3. Describe predictability of initial aircraft response.	Collective input results were not predictable due to light damping. Would still be climbing with only 80% torque. No idea how to control drift. No position keeping symbology available. Heading maintenance was easy to control.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to overshoot the vertical axis. Could not predict what outcome collective inputs would have. Time available for the maneuver was consumed by attempting to hit the target altitude. Tendency to over control the collective inputs.
5. Describe strategy for performing the task.	The strategy was to control heading, altitude, and position in that order. Controlled one axis at a time.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, VSI, RADALT, velocity vector and acceleration cue. Need hover position box symbology. VSI was too sensitive for a lightly damped collective. Heading tape useless during turn because it moved to fast to be readable.

Pilot 4: – Task: Bob-up **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Able to meet desired an adequate after developing a strategy for executing the maneuver.
2. Describe how aggressive and how precise you could perform the task.	Could perform maneuver with relative precision except for altitude excursions and drift.
3. Describe predictability of initial aircraft response.	A/C responds in yaw and pitch as anticipated. Collective is predictable during initial rate of ascent but response is not immediate when attempting to arrest the rate of climb.
4. Describe any objectionable oscillations or tendency to overshoot.	There was a tendency to overshoot altitude. Collective response was not predictable and caused a moderate workload.
5. Describe strategy for performing the task.	Started slow climb rate first before beginning yaw. Arrived at altitude before arriving at desired heading. Only manage one parameter at a time.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, RADALT, VSI

Pilot 5: – Task: Bob-up **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Was not able to perform within adequate time constraints. Had to sacrifice time for performance of other parameters. It was not possible to attain adequate performance in your timing of the maneuver if you wanted to maintain adequate performance of other tasks.
2. Describe how aggressive and how precise you could perform the task.	Was not aggressive enough in the yaw axis to complete the maneuver in adequate time. The heading tape has its own rate which is not the aircraft yaw rate. As you moved your head the heading tape rate increased. This was very confusing. You are lacking the one cue that should be available to the pilot and that's the rate of yaw.
3. Describe predictability of initial aircraft response.	Not predictable. Increased yaw rate makes heading capture unpredictable. Workload to control heading causes altitude to be affected due to limited attention span available for crosscheck. Collective input/output not predictable. Too sensitive. With VelStab off position hold becomes a cross check and workload driver. The velocity vector and acceleration cue can't be allowed to build rates that are very difficult to control.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to chase the altitude because the collective response is not linear. Could not hold position. Velocity vector and acceleration cues are not predictable or usable to maintain position.
5. Describe strategy for performing the task.	The strategy was to find the heading, apply power, apply yaw rate and while tracking heading. Keep your acceleration cue in the center then check radar altitude to make sure your rate of climb isn't anything excessive. Repeat the scan.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Missing – cue for yaw acceleration rate. The heading tape was not a good indicator. Objectionable – heading tape moves too rapidly to be a usable cue for yaw rate. Digital heading moves too fast. Heading tape can be disorienting.

Pilot 6: – Task: Bob-up **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Did not achieve desired or adequate standards. Had great difficulty with altitude control. Could not arrest a 300-400 fpm rate of climb.
2. Describe how aggressive and how precise you could perform the task.	Not precise on altitude or position. Lack of appropriate response to collective input caused performance degradation. Heading tape movement made me dizzy. Could not be precise in position maintenance.
3. Describe predictability of initial aircraft response.	Controller is predictable in yaw but not in heave. Control of position was not predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	Overshot altitude every time.
5. Describe strategy for performing the task.	Start a slow climb then managed heading then went back to catch altitude before it exceeding target. Tried to roll out on heading before altitude.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, RADALT, VSI, velocity vector, acceleration cue. Altitude control was the most objectionable control feature. Had difficulty reading the heading tape and the digital readout during rapid turns. Heading tape was so far up in the visual field that there was a tendency to tilt the head back and look up at it. This made the symbology at the bottom unreadable.

Pilot 1: – Task: Bob-up **Symbology: Compressed**	**Flight Control System: VelStab** **HQR Rating: 4.5 –** HQR 4. Minor deficiencies. Desired performance required considerable pilot compensation. HQR 5. Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Altitude required a one-time input to hit target altitude within 2 feet with occasional 5 foot overshoot. Workload low. No attempt to control position. Let flight controls do it. Heading control only required small adjustments.
2. Describe how aggressive and how precise you could perform the task.	Aggressive. Close to full yaw input. Could be as aggressive as flight controls would allow.
3. Describe predictability of initial aircraft response.	Beak-away force on the SAC vertical axis very heavy. A/C response was very predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	No oscillations or overshoot problems except with heading – tendency to overshoot.
5. Describe strategy for performing the task.	No comments provided.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading, RADALT, VSI.

Pilot 2: – Task: Bob-up **Symbology: Compressed**	**Flight Control System: VelStab** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Could not perform adequately in maintaining hover position. VelStab Hover Hold cannot handle this aggressive a maneuver. Heading was easy to control. Did not attempt to solve the drift problem.
2. Describe how aggressive and how precise you could perform the task.	Could not be aggressive due to the dual axis task workload. Could not be precise with two axis (altitude and heading) to manage.
3. Describe predictability of initial aircraft response.	Could not predict of solve the drift problem. VelStab could not reliably hold position to adequate standards.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to overshoot position maintenance.
5. Describe strategy for performing the task.	Had to time-share between heading and altitude. Led with heading and tried not to exceed 400 fpm rate of climb.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, RADALT, VSI, ROC symbology. Did not attempt to manage the velocity vector or acceleration cue. That was left to VelStab to manage.

Pilot 3: – Task: Bob-up **Symbology: Compressed**	**Flight Control System: VelStab** **HQR Rating: 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Heading was not an issue with compressed symbology. Being able to see the desired heading at all times reduced workload and cross check time. Altitude maintenance was most difficult. Could not get a consistent rate of climb.
2. Describe how aggressive and how precise you could perform the task.	Could not be aggressive or precise except in heading. Tradeoff between ROC and altitude capture. Had to control ROC to 300-400 fpm in order to achieve adequate altitude.
3. Describe predictability of initial aircraft response.	Altitude control was not predictable due to lightly damped collective. VSI symbology however was much easier to use than contact analog because it was more predictable and a better analog indicator of rate.
4. Describe any objectionable oscillations or tendency to overshoot.	Overshot altitude. Collective input sensitive and difficult to manage. Wrist coupling on the SAC caused some overshoot in the lateral axis.
5. Describe strategy for performing the task.	Start turn then climb at less than 400 fpm. Having the target heading in view during the entire maneuver freed up time to manage altitude.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, VSI, RADALT. Need a hover position box.

Pilot 4: – Task: Bob-up **Symbology: Compressed**	**Flight Control System: VelStab** **HQR Rating: 3 –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Able to meet desired performance in all parameters.
2. Describe how aggressive and how precise you could perform the task.	Was relatively aggressive and precise.
3. Describe predictability of initial aircraft response.	Collective input and timing had to be precise to successfully complete the maneuver. Really concentrated on maintaining a controlled ROC. VelStab held position. Easy to roll out on correct heading. Cyclic response was predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	No objectionable oscillations. There was a real potential for overshooting altitude. You really had to concentrate and manage that parameter. Heading had a potential for overshoot but was manageable and not objectionable. Paid most attention to altitude management vs. heading.
5. Describe strategy for performing the task.	Started a moderate turn before climbing in altitude. Looked for a 10- to 15-ft altitude lead before releasing the collective trigger. Managed heading after altitude.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape was very useful. Compressed feature helped to predict when to roll out.

Pilot 5: – Task: Bob-up **Symbology: Compressed**	**Flight Control System: VelStab** **HQR Rating: 3 –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Met desired performance.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive but precise. Not a lot of head induced interference.
3. Describe predictability of initial aircraft response.	Was predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	Some oscillations in altitude.
5. Describe strategy for performing the task.	Monitor ROC and keep it 300- to 400-fpm rate. Put in a rapid yaw rate then managed altitude.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Compressed heading tape helped in that you could see the target heading throughout the turn. It reduced workload because it freed up some mental cross check time to manage altitude.

Pilot 6: – Task: Bob-up **Symbology: Compressed**	**Flight Control System: VelStab** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Met desired standards without difficulty.
2. Describe how aggressive and how precise you could perform the task.	Aggressive and precise ±2 ft and right on the heading. VelStab did not hold position very well.
3. Describe predictability of initial aircraft response.	VelStab was very predictable. A/C response to pilot input was predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	Slight tendency to overshoot altitude.
5. Describe strategy for performing the task.	Split scan between heading and altitude. Looked at VSI to ensure minimal rate of climb.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, VSI, RADALT Nothing to add.

Pilot 1: – Task: Bob-up **Symbology: Compressed**	**Flight Control System: AFCS** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Biggest issues were position maintenance and altitude capture workload. Easy to meet desired performance on heading. No cues for position maintenance over hover point. Altitude capture easier with more collective friction.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive. Altitude capture was difficult.
3. Describe predictability of initial aircraft response.	Collective input was non-linear with respect to rate of climb. This caused objectionable oscillations in the vertical axis.
4. Describe any objectionable oscillations or tendency to overshoot.	Collective input was non-linear with respect to rate of climb. This caused objectionable oscillations in the vertical axis. Collective friction increase helped with PIO tendency.
5. Describe strategy for performing the task.	Started climb and vertical climb simultaneously.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, RADALT, acceleration cue, velocity vector and ROC indicator.

Pilot 2: – Task: Bob-up **Symbology: Compressed**	**Flight Control System: AFCS** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Controlling altitude is very difficult. The collective is hard to set and get useful feedback. Heading is the easiest parameter to control.
2. Describe how aggressive and how precise you could perform the task.	Precision is poor in altitude control. Control forces are excessive in the yaw axis. Could not be aggressive.
3. Describe predictability of initial aircraft response.	Could not set the collective and maintain 300-fpm climb rate. Collective response seems non-linear and difficult to predict what reaction you will get with small collective inputs.
4. Describe any objectionable oscillations or tendency to overshoot.	Strong tendency to overshoot the vertical axis. Only small amount of overshoot on the yaw axis.
5. Describe strategy for performing the task.	Attempted to limit ROC to 300 fpm while turning. This proved difficult.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, VSI, RADALT were primary.

Pilot 3: – Task: Bob-up **Symbology: Compressed**	**Flight Control System: AFCS** **HQR Rating: 6 –** Very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Could not determine or maintain ground position with the available symbology. Heading was easy to manage because the roll out heading was in view at all times.
2. Describe how aggressive and how precise you could perform the task.	Could be very aggressive with heading. You could see the roll out heading at all times. Confidence in heading maintenance allowed you to focus on other parameters such as altitude.
3. Describe predictability of initial aircraft response.	Altitude maintenance was more predictable in AFCS than in VelStab because you did not have to guess at when to release the collective trigger to engage altitude hold. You controlled level off manually.
4. Describe any objectionable oscillations or tendency to overshoot.	Some tendency to overshoot altitude.
5. Describe strategy for performing the task.	Aggressive yaw input to get the turn started then managed the vertical axis. Kept a low ROC so heading was reached before altitude.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Need position maintenance symbology. Used heading tape, VSI, RADALT.

Pilot 4: – Task: Bob-up **Symbology: Compressed**	**Flight Control System: AFCS** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Able to meet desired to adequate for heading and altitude. Was outside adequate for time.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive. Pilot workload high. Tended to overshoot altitude by 50 ft. Was able to be precise with heading.
3. Describe predictability of initial aircraft response.	Collective response was not predictable. Collective input did not match the response. Cyclic was precise and predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	Overshot altitude by a wide margin. Stopping at and maintaining a prescribed altitude was a high workload task.
5. Describe strategy for performing the task.	Started a moderate turn before climbing in altitude. Tried unsuccessfully to lead altitude with collective. Managed heading after altitude.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Controlling altitude was a high workload task. Very difficult to stop climb at a precise altitude. Outcome of collective adjustments was not predictable. Hard to determine about of altitude over/undershoot for a given collective input.

Pilot 5: – Task: Bob-up **Symbology: Compressed**	**Flight Control System: AFCS** **HQR Rating: 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Turn rate management kept from being desired on time. Met desired in other axis.
2. Describe how aggressive and how precise you could perform the task.	Could not be aggressive due to workload in managing turn rate, altitude and position.
3. Describe predictability of initial aircraft response.	A/C response to control input was predictable. Collective input sensitivity made the task more difficult. High workload.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to overshoot altitude. Large collective inputs caused oscillation in other axis.
5. Describe strategy for performing the task.	Looked off axis. Increased collective to build a ROC then introduce yaw. Maintained 200- to 300-fpm ROC.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Power management predictability made the workload high. Collective was sensitive. This caused over/undershooting of altitude target. The VSI proximity to the RADALT was useful for cross check. The compressed heading tape was a good feature because target heading could be seen at all times which reduced workload.

Pilot 6: – Task: Bob-up **Symbology: Compressed**	**Flight Control System: AFCS** **HQR Rating: 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Able to meet adequate standards. Could not hold position. Heading was easy to manage. Altitude was difficult due to collective sensitivity.
2. Describe how aggressive and how precise you could perform the task.	Can be aggressive with the turn but not with altitude control. The collective sensitivity workload is high.
3. Describe predictability of initial aircraft response.	Collective response was not predictable. Turn was difficult due to wrist coupling on the SAC where there was a tendency to mix hover turn with lateral movement.
4. Describe any objectionable oscillations or tendency to overshoot.	Overshot altitude due to collective sensitivity.
5. Describe strategy for performing the task.	Start the turn first then pull collective to gain altitude trying not to exceed 400-fpm climb rate. Rolled out on heading and tried to stop climb at target altitude.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, VSI, RADALT. Need position keeping symbology.

TRANSIENT TURN

Pilot 2: – Task: Transient Turn **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	With VelStab on you have to take control from Heading Hold to nail the heading. You had to fight a little to get to your target heading. Tendency to fixate on the heading tape and lose track of the horizon line. Had to force wings level to make the time. Less of the tape is visible when turning right vs. left. Had to search for horizon line mixed in with heading tape and other symbology.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive. Modest at best. Lateral SAC control forces were high. Slope and gradient is high and cannot get a controlled input.
3. Describe predictability of initial aircraft response.	Have to fight heading hold capture to get to the target heading. Aircraft response is generally predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	Oscillation to gain control of heading from VelStab.
5. Describe strategy for performing the task.	Get the bank angle in as soon as possible and try not to over drive the lateral controller. Use A/S as a pitch control cue.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, horizon line. The perceived heading error with the uncompressed heading tape was greater than the actual error. Shortening of the heading tape and driving into the upper corner of the display provides less heading information than required for the maneuver. There is too much information that is not available. Would like to see target heading sooner to better predict when to roll out of the turn.

Pilot 3: – Task: Transient Turn **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Altitude was maintained by VelStab. Digital heading was primarily used for heading. The heading tape moved too fast to be useable except during the roll out portion of the turn. Had difficulty in determining and consistently achieving desired bank angle. Symbology cues were not there for bank. No usable pitch cues.
2. Describe how aggressive and how precise you could perform the task.	Tempered aggressiveness. Could not be precise with bank angle. Never consistently captured the desired angle. Limited amount of heading tape available in bank. Had to skew head position to read the heading tape.
3. Describe predictability of initial aircraft response.	Pitch and roll angles were not predictable due to a lack of precise cueing symbology for determining attitude. Since adequate pitch angle references were not available had to use airspeed as a pitch reference – declining A/S – nose up – increasing A/S nose down.
4. Describe any objectionable oscillations or tendency to overshoot.	Overshot bank angle due to lack of adequate symbology cues. Guessed at bank angle.
5. Describe strategy for performing the task.	Ramped in and out of turns. Used A/S to determine and control pitch attitude. Kept head 45° off axis in the direction of turn.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, A/S, VSI, barometric altitude. Missing symbology – no precise pitch attitude cues, no bank angle cues. Could use a pitch ladder when FLIR is degraded.

Pilot 4: – Task: Transient Turn **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Met desired criteria most of the time.
2. Describe how aggressive and how precise you could perform the task.	Aggressive in rolling into the turn. Held bank angle and made minor adjustments. Fairly precise in executing maneuvers.
3. Describe predictability of initial aircraft response.	Cyclic response was predictable. There was not much collective required due to VelStab ALT HOLD.
4. Describe any objectionable oscillations or tendency to overshoot.	No oscillations or tendency to overshoot.
5. Describe strategy for performing the task.	Ground cues could not be used. Horizon line was the only reference for roll out. Brought head back in to see lubber line to gage rate of turn with digital readout.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape was not much use during turns because it moved to fast to be able to read the numbers.

Pilot 5: – Task: Transient Turn Symbology: Contact Analog	**Flight Control System: VelStab** **HQR Rating: 2 –** Good – Negligible deficiencies. Pilot compensation not a factor for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Met desired performance across the board. Good aircraft handling characteristics. VelStab does a good job of taking care of altitude and airspeed. Actual angle of bank is a guess. No symbology to tell exactly what the bank angle is. The target was 30° or so.
2. Describe how aggressive and how precise you could perform the task.	Was not that aggressive. The heading tape moves too fast to be readable or usable during the turn. Could not be precise on angle of bank. No symbology to tell what the angle was in precise degrees.
3. Describe predictability of initial aircraft response.	A/C performance was predictable in altitude and airspeed which were controlled by VelStab. This permitted concentration on roll rate and roll out. Could not determine angle of bank precisely.
4. Describe any objectionable oscillations or tendency to overshoot.	There was no overshoot provided the bank angle was less than 40°.
5. Describe strategy for performing the task.	Roll in to about 40-45° bank angle to ensure time would be met. Took out 5° prior to roll out to ensure precision. Got only 1° overshoot with this method.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape caused some disorientation due to the angle, shortened amount of tape in view, the conflict with the horizon line, and the speed of movement. Missing – bank angle and turn rate symbology. Earth referenced horizon line was not usable as an angle of bank indicator especially with the head turned.

Pilot 6: – Task: Transient Turn **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Mostly met desired standards with some adequate. Could not determine bank angle with available symbology. Moderate workload.
2. Describe how aggressive and how precise you could perform the task.	Could have been more aggressive if angle of bank was precise. No symbology to know exactly what the bank angle was. Felt like every turn was a different bank angle. Heading was easy to manage and precise.
3. Describe predictability of initial aircraft response.	Predictable except for angle of bank. Had to hold pressure on SAC to maintain rate. Angle of bank was not predictable due to lack of symbology.
4. Describe any objectionable oscillations or tendency to overshoot.	Slight tendency to overshoot heading. VelStab caused heading oscillations during roll out. It attempts to engage heading hold while you are adjusting causing a 1-2° oscillation from the intended heading.
5. Describe strategy for performing the task.	Picked out screen fixed symbology to put the horizon line on to hold the 30° bank angle. Tried to keep the lubber line in sight.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Horizon line, heading tape. Need symbology to assist in determining precise angle of bank. The iron wings were worthless and often not in view. Tendency to tilt head back to read heading tape which is too high in the HMD FOV. Symbology is too spread out which slows cross check. Don't like the heading tape moving with head movements. Need precise bank angle symbology.

Pilot 2: – Task: Transient Turn **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	A/C more maneuverable without VelStab on – gains in roll – losses in pitch. No way to control altitude precisely with no precise attitude symbology feedback.
2. Describe how aggressive and how precise you could perform the task.	Controller characteristics maneuver better in roll with VelStab off however altitude capture is more difficult. Heading capture is good. Tape is so big the perceived distance of 10° is disconcerting. There is a sense of wandering with the heading tape vs. the digital readout.
3. Describe predictability of initial aircraft response.	Cannot crisply roll out on a heading. There is noticeable lateral pitch coupling. Also some oscillation in pitch due to lack of precise pitch reference. Need a pitch ladder for precision in this maneuver.
4. Describe any objectionable oscillations or tendency to overshoot.	Noticeable oscillation in heading and altitude.
5. Describe strategy for performing the task.	Set roll angle then adjusted pitch by watching A/S then concentrated on heading.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, altimeter. Heading tape is too short while in turns to provide enough heading information to anticipate when to roll out. The target heading comes up too quickly. Need to see more heading tape during this maneuver.

Pilot 3: – Task: Transient Turn **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Had a few maneuvers that exceeded adequate standards. Used VSI and pitch attitude to maintain altitude. Used a ramp in and out technique for rolling into and out of turns. Did not have good pitch attitude symbology cues. Could capture heading ±2°.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive due to lack of pitch and bank angle cues. Had to ramp in and out of turns.
3. Describe predictability of initial aircraft response.	Pitch angle was not predictable due to lack of adequate symbology cues.
4. Describe any objectionable oscillations or tendency to overshoot.	Slight PIO in roll axis. Some tendency to overshoot heading.
5. Describe strategy for performing the task.	Ramping in and out of turns helped control pitch attitude and altitude. Used VSI and pitch to maintain A/S. Looked over nose and used iron wings and horizon line to maintain attitude.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, VSI, horizon reference, iron wings, altimeter, A/S indicator. Objectionable – Heading tape was driven up into the top corner of the display making the viewable portion very short. Missing symbology – Pitch ladder and bank angle cues.

Pilot 4: – Task: Transient Turn **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Met desired in heading and time only. Met adequate in A/S and sometimes altitude.
2. Describe how aggressive and how precise you could perform the task.	Aggressive in rolling into and out of the turns. Precise in heading but not altitude.
3. Describe predictability of initial aircraft response.	Pitch coupling caused A/S and altitude excursions. Altitude maintenance was difficult and a moderate workload.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to overshoot when using the collective. Horizon line was not useable because it was often out of the field of view.
5. Describe strategy for performing the task.	Used heading tape to set bank angle. Looked at heading tape then digital readout then back to the tape when the lubber line came into view.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Horizon line was not usable during high angles of bank and aggressive turns. It was out of the field of view most of the time.

Pilot 5: – Task: Transient Turn Symbology: Contact Analog	**Flight Control System: AFCS** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Able to meet desired and adequate performance.
2. Describe how aggressive and how precise you could perform the task.	Aggressiveness was a tradeoff for preciseness. The higher the angle of bank the easier it was to make time but harder to manage altitude and heading roll out. Had to be less aggressive in bank angle to manage other axis.
3. Describe predictability of initial aircraft response.	AFCS was more predictable than VelStab. You could hold attitude and command a rate very precisely.
4. Describe any objectionable oscillations or tendency to overshoot.	Had a tendency to overshoot altitude.
5. Describe strategy for performing the task.	Located target heading in advance of maneuver with head movement. Led the turn with power to maintain altitude. Took power out during roll out.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	No way to accurately determine precise bank angle. Wide spread of the symbology across the display slowed cross check. Objectionable – rapid head movements can be confused with aircraft movements. This causes some spatial disorientation. Need to be able to see more of the heading tape. Takes more concentration to use the shorter tape.

Pilot 6: – Task: Transient Turn **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 7 –** Major deficiencies. Adequate performance not obtainable with maximum pilot compensation. Controllability not in question.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Not adequate in altitude control. Mostly adequate in other axis.
2. Describe how aggressive and how precise you could perform the task.	No precision in altitude control. Could not figure out a power setting for a level turn. Collective sensitivity and predictability was an issue.
3. Describe predictability of initial aircraft response.	Collective position and power management was not predictable. Pitch seemed more sensitive than roll. Guessed at control positions.
4. Describe any objectionable oscillations or tendency to overshoot.	Overshot both heading and altitude. Oscillations in roll axis.
5. Describe strategy for performing the task.	Got the bank started then managed level altitude by watching the VSI.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, VSI, RADALT, A/S. Symbology spread too far apart for an efficient crosscheck. This affected altitude control. Heading tape moves with the head and is confusing along with aircraft movement. Need a turn and bank indicator.

Pilot 2: – Task: Transient Turn Symbology: Compressed	**Flight Control System: VelStab** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Controllable - better than adequate for about 2/3 of the turns. Maintaining altitude is not an issue. VelStab handles it up to about 45° angle of bank.
2. Describe how aggressive and how precise you could perform the task.	Difficult to be aggressive and be precise with heading and altitude. Stick forces are too high. Difficult to hold stick position in high angle of bank.
3. Describe predictability of initial aircraft response.	Predictable response when rolling into the turn up to about 45° angle of bank. At that point it becomes much less predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	When turns approach 45° there is a most noticeable oscillation. Turns closer to 30° are much more controllable.
5. Describe strategy for performing the task.	Maintained airspeed constant by putting the nose of the A/C a little below the horizon.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, barometric altimeter, VSI, iron wings and horizon line.

Pilot 3: – Task: Transient Turn Symbology: Compressed	**Flight Control System: VelStab** **HQR Rating: 2 –** Good – Negligible deficiencies. Pilot compensation not a factor for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	VelStab held altitude. This freed you up to manage heading. Compressed tape made heading management easy because you could see the target heading at all times during the maneuver.
2. Describe how aggressive and how precise you could perform the task.	Could be very aggressive. Good roll rates and easy to roll out on the desired heading without much attention or workload.
3. Describe predictability of initial aircraft response.	Predictable. No problem with bank angle using the horizon line.
4. Describe any objectionable oscillations or tendency to overshoot.	No noticeable oscillations. However, there was some cross coupling in the wrist using the SAC causing a roll pitch coupling.
5. Describe strategy for performing the task.	Set the horizon line on a bank angle then monitored heading tape and VSI. Did not focus on A/S which VelStab controlled.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, altimeter, A/S, VSI. VSI was much easier to use than Contact Analog. It gave a better and more predictable analog indication of rates that were easier to manage. Compressed heading tape was easier and required less cross check workload to manage over Contact Analog.

Pilot 4: – Task: Transient Turn Symbology: Compressed	**Flight Control System: VelStab** **HQR Rating: 3 –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Able to meet desired performance for all parameters.
2. Describe how aggressive and how precise you could perform the task.	Aggressive. A/C handled well. Was able to get a 30° bank angle without problem.
3. Describe predictability of initial aircraft response.	Cyclic was predictable and precise.
4. Describe any objectionable oscillations or tendency to overshoot.	None.
5. Describe strategy for performing the task.	Noted cyclic position for the desired 30° bank angle and duplicated it for each turn. Used the line of sight cue to position the horizon line for a level turn.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Used the LOS symbol as the iron wings to position the horizon line for a level turn.

Pilot 5: – Task: Transient Turn Symbology: Compressed	**Flight Control System: VelStab** **HQR Rating: 3 –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	VelStab assisted in ability to achieve desired in all parameters.
2. Describe how aggressive and how precise you could perform the task.	The more aggressive you were the less predictable the outcome. Higher angles of bank increased workload and decrease accuracy.
3. Describe predictability of initial aircraft response.	Attitude command control system. There is no symbology to tell how much control pressure is needed to attain the desired angle of bank and turn rates.
4. Describe any objectionable oscillations or tendency to overshoot.	None.
5. Describe strategy for performing the task.	Put the horizon line on other fixed symbology to maintain a constant bank angle.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Used heading tape, altimeter, A/S, FPV, and horizon line. With compressed heading tape there was no confusion between aircraft movement and head movement. Need precise bank angle symbology.

Pilot 6: – Task: Transient Turn Symbology: Compressed	**Flight Control System: VelStab** **HQR Rating: 3 –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Met desired/adequate performance. Fairly easy to hold altitude and airspeed.
2. Describe how aggressive and how precise you could perform the task.	Fairly aggressive. Small heading overshoot.
3. Describe predictability of initial aircraft response.	Bank angle not predictable. There is no symbology available for precise bank indication. Had to roll in then adjust each time. A/C response was predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	Slight tendency to overshoot heading on the roll out 1-2°.
5. Describe strategy for performing the task.	Spend most of the cross check time with heading management with an occasional look at altitude and airspeed.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Need precision bank angle symbology. Compressed heading tape was predicable and easy to use because you could see your target heading at all times during the turn.

Pilot 2: – Task: Transient Turn Symbology: Compressed	**Flight Control System: AFCS** **HQR Rating: 6 –** Very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Rated a 6 because with 45° or more bank angle the nose begins to tuck. Cross coupling causes you to have to chase the correct stick input.
2. Describe how aggressive and how precise you could perform the task.	Cannot meet desired more than 50% of the time due to timing. Don't have time to deal with altitude maintenance. Managing A/S and heading is about a 50/50 proposition.
3. Describe predictability of initial aircraft response.	Aircraft is not predictable at high angles of bank with aggressive stick input. Performance between desired, adequate, and not adequate is not predictable or consistent.
4. Describe any objectionable oscillations or tendency to overshoot.	When you roll out quickly to nail the desired heading you get an attitude oscillation. Higher angles of bank cause tendency to overshoot desired heading even with a good lead.
5. Describe strategy for performing the task.	Tried to keep the iron wings slightly below the horizon to maintain altitude and airspeed. This was difficult at high bank angles.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	

Pilot 3: – Task: Transient Turn Symbology: Compressed	**Flight Control System: AFCS** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Easy to achieve desired heading due to compressed presentation. Tradeoff between bank angle and heading maintenance. The higher the angle of bank the greater the altitude excursions.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive. Had some negative habit transfer issues going from attitude to rate command. Without VelStab had to hand fly more axis.
3. Describe predictability of initial aircraft response.	Heading predictable. Tended to overshoot bank angle a little.
4. Describe any objectionable oscillations or tendency to overshoot.	Some self-induced oscillations in bank angle.
5. Describe strategy for performing the task.	Roll into the turn, put the horizon line on the 1000-ft hash mark of the VSI and then monitor and manage the VSI. Checked heading, horizon line and line of sight cue for attitude maintenance.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, altimeter, VSI, A/S, horizon line. Nothing objectionable or missing.

Pilot 4: – Task: Transient Turn Symbology: Compressed	**Flight Control System: AFCS** **HQR Rating: 4 –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Able to meet adequate standards at all times. Met desired standards most of the time.
2. Describe how aggressive and how precise you could perform the task.	Was more aggressive than intended. This had a negative affect on preciseness. Had to back off on aggressiveness in order to maintain bank angle. This led to altitude excursions.
3. Describe predictability of initial aircraft response.	Initial A/C response unpredictable. Had to see what the response was then adjust as required to maintain bank angle. Collective was as expected.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to overshoot bank angle. Expected 30° angle of bank and got 45°. Airspeed was relatively constant. Experienced some pitch oscillation in left turns.
5. Describe strategy for performing the task.	Noted cyclic position for the desired 30° bank angle and duplicated it for each turn but tended to overshoot and had to adjust. Used the line of sight cue to position the horizon line for a level turn.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	LOS cue, heading tape, altimeter, VSI.

Pilot 5: – Task: Transient Turn Symbology: Compressed	**Flight Control System: AFCS** **HQR Rating: 3 –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Achieved desired standards. Workload was moderate.
2. Describe how aggressive and how precise you could perform the task.	The more aggressive you were the less precise. Could not keep up with cross check if very aggressive.
3. Describe predictability of initial aircraft response.	Collective overly sensitive. Tendency to overshoot altitude. No bank angle indication so angle was not precise. Pitch angle was difficult to predict.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency for A/C to pitch down during steep turn. This increases A/S. Additional power required when you roll into the turn. Overshot altitude due to collective sensitivity.
5. Describe strategy for performing the task.	Rolled into turn, increase power, put the horizon line on the RADALT symbology to maintain bank angle.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Need a precise bank angle indication. This was not provided.

Pilot 6: – Task: Transient Turn Symbology: Compressed	**Flight Control System: AFCS** **HQR Rating: 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Met adequate performance.
2. Describe how aggressive and how precise you could perform the task.	Could not be aggressive due to workload in managing altitude.
3. Describe predictability of initial aircraft response.	Cyclic forces seemed light rolling into the turn which caused some roll overshoot.
4. Describe any objectionable oscillations or tendency to overshoot.	Overshot heading and bank angle.
5. Describe strategy for performing the task.	Kept a good cross check going.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading, VSI, altimeter, horizon line. Did not pay much attention to A/S or torque. No symbology to determine precise angle of bank.

TRAFFIC PATTERN

Pilot 1: – Task: Traffic Pattern **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: TP 3 –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance. **Approach: 6 –** Very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Responsiveness of engine and flight controls for altitude hold difficult to manage. Altitude hold slow to engage. Had to manually reduce collective to stop climb with collective input.
2. Describe how aggressive and how precise you could perform the task.	Would not attempt to be aggressive
3. Describe predictability of initial aircraft response.	Adjusting rate of climb was not predictable. Other than that issue aircraft response was predictable. Sometimes used too much collective. Difficult to predict A/C response to power application.
4. Describe any objectionable oscillations or tendency to overshoot.	VelStab made it harder to make adjustments in rate of descent. Made it harder to arrest high rate of descent.
5. Describe strategy for performing the task.	Used rate of climb indicator to make large adjustments and SAC to fine tune altitude
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Used all symbology available. Altitude hold was not responsiveness. When using steeper rate of turn with VelStab tendency to overshoot by 3-4°

Pilot 2: – Task: Traffic Pattern **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 3 (TP) –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance. **HQR 4 (Approach) –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	VSI difficult to control within limits.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive but precise.
3. Describe predictability of initial aircraft response.	Predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	No oscillation. Tendency to overshoot altitude due to the VSI symbology. Airspeed hard to control.
5. Describe strategy for performing the task.	None described.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	VSI, heading tape, altimeter, FPV, airspeed indicator.

Pilot 3: – Task: Traffic Pattern **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 3 (TP) –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance. **HQR 5 (Approach) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	No difficulty in meeting desired standards for the traffic pattern. During approach, iron wings and horizon line are driven off the display by as little as an 8° approach. The maneuver called for a 12° approach. Was able to use the FPV for the approach once the aircraft began to decelerate.
2. Describe how aggressive and how precise you could perform the task.	Precise maneuvering in the traffic pattern. FPV helped bring workload down during the steep approach.
3. Describe predictability of initial aircraft response.	Was able to use the horizon line and iron wings in the turns. No horizon line during the approach so maintaining wings level was done by using the heading tape. Could not be precise in decelerative attitude due to lack of pitch cues. After initial deceleration, the A/S bled off rapidly and the A/C fell through the approach angle.
4. Describe any objectionable oscillations or tendency to overshoot.	Experienced some roll oscillation due to the SAC. During approach experienced some minor yaw axis oscillation with collective input.
5. Describe strategy for performing the task.	Used shallow bank angles in turns. Got the deceleration in early. Put the FPV on the touchdown point and held it during the steep approach. This really helped maintain a constant approach angle. Without it, you would be guessing.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, VSI, FPV, altimeter, airspeed indicator. Objectionable – Horizon line and iron wings were not visible during steep approach where the head is looking down at the touch down point. There were no precise pitch cues to assist with determining the appropriate attitude for deceleration and for maintaining the approach angle.

Pilot 4: – Task: Traffic Pattern **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 4 (TP) –** Minor deficiencies. Desired performance required considerable pilot compensation. **HQR 5 –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Able to meet desired standards for the traffic pattern.
2. Describe how aggressive and how precise you could perform the task.	Could perform as aggressively as needed during the traffic pattern. The approach was more challenging.
3. Describe predictability of initial aircraft response.	During traffic pattern the A/C response was as expected. Collective for altitude control and cyclic for turn roll out were as expected. Tried to maintain constant approach angle but had a tendency to undershoot or fall through.
4. Describe any objectionable oscillations or tendency to overshoot.	2-3° oscillation either side of desired heading. VelStab attempts to hold a heading during fine tuning to desired heading which causes the oscillation. During the approach the A/S and rate of closure were difficult to perceive. Ended up fast at the bottom of the approach.
5. Describe strategy for performing the task.	Monitored altitude, A/S, and Hdg during the traffic pattern. During the approach traded altitude and A/S until A/S was below 60 then flew the FPV to maintain approach angle. Below 20 kts used velocity vector.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Pitch attitude cues were not usable during steep approach because the horizon line was glued to the top of the display. Could have used a better attitude reference symbology during approach.

Pilot 5: – Task: Traffic Pattern **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 3 (TP) –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance. **HQR 5 (Approach) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Easy to meet desired standards during the traffic pattern. The approach was very challenging and high workload.
2. Describe how aggressive and how precise you could perform the task.	No need to be aggressive with the traffic pattern. Was more aggressive during the approach but not very precise. Not a good feeling for rate of descent. Could not judge the amount of aft cyclic force required for deceleration.
3. Describe predictability of initial aircraft response.	There seemed to be a heavy SAC force required to accelerate to 80 kts during traffic pattern. During the approach, the amount of aft cyclic required to decelerate was not predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	Slight tendency to overshoot heading during the traffic pattern. During the approach it was very difficult to control A/S and descent angle.
5. Describe strategy for performing the task.	Concentrated on reducing A/S to begin approach. Used FPV to maintain approach angle.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	No useable horizon information available. Difficult to control A/S during approach with no cues to tell you what you were doing. Difficult to maintain a constant rate of descent with the VSI symbology. Difficult to determine and maintain a constant rate of closure and approach angle.

Pilot 6: – Task: Traffic Pattern **Symbology: Contact Analog**	**Flight Control System: VelStab** **HQR Rating: 3 (TP) –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance. **HQR 4 (Approach) –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Met desired standards. Traffic pattern was fairly easy.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive because the maneuver did not demand it. Was able to be precise in altitude and heading.
3. Describe predictability of initial aircraft response.	Predictable. No problems.
4. Describe any objectionable oscillations or tendency to overshoot.	Some oscillation in heading due to the large space between numbers. Put in larger than needed corrections.
5. Describe strategy for performing the task.	No real strategy. Straight forward maneuver and control inputs.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, altimeter, A/S.

Pilot 1: – Task: Traffic Pattern **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 5 (TP) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation. **HQR 4 (Approach) –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Workload was high without proprioceptive cues. Airspeed maintenance was due to lack of sufficient pitch attitude cues. Attitude maintenance was also an issue. Heading maintenance not a problem. On approach attaining proper steep angle caused moderate workload flying the Flightpath Vector (FPV)
2. Describe how aggressive and how precise you could perform the task.	Not aggressive due to close in traffic pattern. Wider pattern may have improved performance.
3. Describe predictability of initial aircraft response.	Rate of climb not predictable with power/collective settings.
4. Describe any objectionable oscillations or tendency to overshoot.	Slow to cross check aircraft altitude. This caused some oscillation and overshoot tendencies.
5. Describe strategy for performing the task.	Traffic pattern was flown in standard manor. Used FPV during approach to maintain steep approach angle and line up with touch down point.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	All symbology available. A more detailed attitude indicator would have helped attitude, airspeed and altitude maintenance.

Pilot 2: – Task: Traffic Pattern **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 5 (TP) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation. **HQR 6 (Approach) –** Very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	About half desired and half adequate performance. Higher level of crosscheck required. Altitude and airspeed hardest to control.
2. Describe how aggressive and how precise you could perform the task.	Hard to be precise. Felt like the aircraft was floating in space without a good horizon reference. Unpleasant feeling. Could not be aggressive.
3. Describe predictability of initial aircraft response.	Tended to overshoot every parameter.
4. Describe any objectionable oscillations or tendency to overshoot.	Worked hard to nail airspeed and altitude. Worked hard to keep altitude, VSI etc. under control
5. Describe strategy for performing the task.	Once climb A/S achieved it was important to manage VSI on crosswind and downwind.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	All symbology required for this maneuver.

Pilot 3: – Task: Traffic Pattern **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 4 (TP) –** Minor deficiencies. Desired performance required considerable pilot compensation. **HQR 5 (Approach) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Heading easy to maintain. Altitude maintenance was more workload due to the sensitivity of the barometric altitude symbology. Was not confident in using the VSI to maintain altitude. Instead, varied A/S to gain or lose altitude. For the approach, the initiation of the maneuver was difficult. There was no horizon line available or iron wings.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive. Was not confident in using the collective due to light damping and lack of predictability of the outcome. A/S maintenance was not predictable due to lack of precise attitude cueing symbology. Could not be aggressive at all on the approach. You fell into the backside of the power curve rapidly with had to be managed.
3. Describe predictability of initial aircraft response.	Managing the vertical axis was difficult and not as predictable due to collective damping. Approaches were not predictable or repeatable with respect to maintaining the approach angle. The FPV really helped maintain angle once you got the airspeed under control.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to vary airspeed due to lack of precise horizon cues.

Pilot 4: – Task: Traffic Pattern **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 4 (TP) –** Minor deficiencies. Desired performance required considerable pilot compensation. **HQR 5 (Approach) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Able to meet desired on altitude heading and speed.
2. Describe how aggressive and how precise you could perform the task.	Was precise during the transition from hover to acceleration to climb. Was less precise in the during climbing turns in holding a constant ROC.
3. Describe predictability of initial aircraft response.	A/C response was as expected from the collective. Experienced some overshoot using the SAC in turns.
4. Describe any objectionable oscillations or tendency to overshoot.	Was not able to precisely control rate of climb and descent. Tended to search. Could not find a single collective setting that would maintain a constant parameter.
5. Describe strategy for performing the task.	None offered.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Used heading tape, A/S, altimeter, and VSI during the traffic pattern. A/S, VSI, FPV during the approach.

Pilot 5: – Task: Traffic Pattern Symbology: Contact Analog	**Flight Control System: AFCS** **HQR Rating: 3 (TP) –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance. **HQR 5 (Approach) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Able to meet desired performance due to the rate command flight control system. Handling qualities were good during traffic pattern. The approach was high workload. Heading tape is distracting and gave false impression the A/C was turning (head movement) when it wasn't.
2. Describe how aggressive and how precise you could perform the task.	Aggressiveness not required for traffic pattern. Could be precise however. Not precise during the approach. Could not determine rate of closure with landing point or exact angle of descent.
3. Describe predictability of initial aircraft response.	Very predictable during the traffic pattern. Rate of deceleration and rate of closure and angle of descent were not predictable during the approach. Collective power changes were not predictable. Very sensitive collective response.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to overshoot altitude and airspeed during the pattern. Tendency to undershoot/overshoot approach angle. Overshot roll out heading on final approach. Could not predict of use the FPV were effectively.
5. Describe strategy for performing the task.	Attempted to used the FPV to maintain the approach angle.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Used heading tape, RADALT, A/S, velocity vector. Heading tape was distracting and gave some false impressions of turning due to head movement. A compressed heading tape would have been less workload to use. Need a horizon reference during the traffic pattern during cruise flight and during approach.

Pilot 6: – Task: Traffic Pattern **Symbology: Contact Analog**	**Flight Control System: AFCS** **HQR Rating: 5 (TP) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation. **HQR 4 (Approach) –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Adequate performance. Altitude management was difficult to hold. Pitch was also sensitive to maintain. During approach, speed was difficult to control.
2. Describe how aggressive and how precise you could perform the task.	Was not precise or aggressive. Slowed the maneuver down to increase accuracy. Had to be aggressive with the collective during the steep approach.
3. Describe predictability of initial aircraft response.	Initial response is predictable but pitch is very sensitive to small input. Had difficulty predicting collective response at the bottom of the approach.
4. Describe any objectionable oscillations or tendency to overshoot.	Overshot heading every time. There was some oscillation in pitch which caused altitude and A/S to be off.
5. Describe strategy for performing the task.	Really worked on managing the VSI to keep in zeroed out. Used cyclic pitch to manage altitude. Used the FPV to manage approach angle.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, velocity vector, acceleration cue, altimeter. Need an angle of bank indication. FPV disappears too high. Could not count the tick marks on the velocity vector due to cross check time constraints.

Pilot 1: – Task: Traffic Pattern Symbology: Compressed	**Flight Control System: VelStab** **HQR Rating: 3 (TP) –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance. **HQR 5 (Approach) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Like scaling of the compressed VSI better than the Contact Analog scale. Flew a two step approach. Tendency to drift left on down wind leg for an unknown reason.
2. Describe how aggressive and how precise you could perform the task.	Fairly aggressive. Very precise rate of climb. Easy to zero rates out.
3. Describe predictability of initial aircraft response.	Liked the ROC indicator. Easy to use – predictable – precise control very easy.
4. Describe any objectionable oscillations or tendency to overshoot.	None.
5. Describe strategy for performing the task.	Stabilized airspeed before initiating climb helped control rates.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Altitude, heading and rate of climb easy to manage with this symbology set.

Pilot 2: – Task: Traffic Pattern Symbology: Compressed	**Flight Control System: VelStab** **HQR Rating: 3 (TP) –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance. **HQR 5 (Approach) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	The traffic pattern was an instrument task. Not difficult to meet the desired standards. The steep approach was difficult. No ability to use horizon line or VSI scale to set up approach. No symbology feedback to tell you what was working.
2. Describe how aggressive and how precise you could perform the task.	Traffic pattern was a very precise task.
3. Describe predictability of initial aircraft response.	Predictable aircraft response during the traffic pattern. ROC was somewhat variable. During the approach, guessed at what to do then had little feedback concerning what adjustments to make. Was not confident during this maneuver.
4. Describe any objectionable oscillations or tendency to overshoot.	None.
5. Describe strategy for performing the task.	Instrument task. No real strategy for the traffic pattern.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, VSI, barometric altitude, A/S symbology.

Pilot 3: – Task: Traffic Pattern Symbology: Compressed	**Flight Control System: VelStab** **HQR Rating: 2 (TP) –** Good – Negligible deficiencies. Pilot compensation not a factor for desired performance. **HQR 4 (Approach) –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Easy to meet desired performance. Small inputs required to maintain heading and A/S. Approach initiation was difficult even with horizon line to determine pitch attitude.
2. Describe how aggressive and how precise you could perform the task.	Not an aggressive task. Could be very precise in holding variables constant. Could not be precise or repeatable on approach entry. Predictability of the amount of control input required for an even deceleration was not there.
3. Describe predictability of initial aircraft response.	High breakout forces required to breakout of hover hold to begin the maneuver. Decelerative attitude for approach entry was not predictable or repeatable.
4. Describe any objectionable oscillations or tendency to overshoot.	Scene content usable on takeoff and climb. No overshoot issues. Tended to overshoot and undershoot the amount of deceleration required to enter the approach. Ended up on the back side of the power curve and fell through the approach angle.
5. Describe strategy for performing the task.	Used scene content to accelerate. Used 50% TQ to get 500-fpm ROC. Used pitch to manage A/S. Cross checked heading, A/S and VSI. Used the FPV to manage steep approach angle.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	The available symbology was very useful. Used nearly all symbols. No undesirable characteristics. Nothing needs to be added to the symbology set. Need to count the cross hatches on the velocity vector to determine speed. This adds workload and slows cross check.

Pilot 4: – Task: Traffic Pattern Symbology: Compressed	**Flight Control System: VelStab** **HQR Rating: 3 (TP) –** Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance. **HQR 4 (Approach) –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Heading easy to maintain. Overshot acceleration to 80kts by 10 kts. Exceeded the 500-fpm ROC occasionally.
2. Describe how aggressive and how precise you could perform the task.	Able to roll out precisely on heading.
3. Describe predictability of initial aircraft response.	More of a pitch rate than anticipated.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to have to hunt for a consistent collective setting to maintain a consistent rate of climb. Caused some variation in ROC. This was operator induced.
5. Describe strategy for performing the task.	None. Straightforward traffic pattern. Used the FPV for the approach.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, VSI, A/S, altimeter, FPV.

Pilot 5: – Task: Traffic Pattern Symbology: Compressed	**Flight Control System: VelStab** **HQR Rating: 3 (TP) –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance. **HQR 5 (Approach) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Easy to meet desired during traffic pattern. Approach was adequate.
2. Describe how aggressive and how precise you could perform the task.	Was not aggressive. VelStab allows for time to be precise on heading. During approach, the steep approach angle make it an aggressive maneuver and more difficult to manage.
3. Describe predictability of initial aircraft response.	Very predictable during the traffic pattern and approach.
4. Describe any objectionable oscillations or tendency to overshoot.	None in the pattern. Over and undershot the approach angle.
5. Describe strategy for performing the task.	Kept cross check going in the pattern. Led turns and generally stayed ahead of the aircraft mentally. On the approach used a 1000-fpm rate of descent with a moderate decel to start the approach. Use FPV to manage approach angle.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Used all available symbology. The VSI was most helpful and very predictable. Liked the fact that the target heading was always in view with the compressed heading tape. Objectionable – the symbology is too spread out which slows cross check.

Pilot 6: – Task: Traffic Pattern Symbology: Compressed	**Flight Control System: VelStab** **HQR Rating: 3 (TP) –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance. **HQR 4 (Approach) –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Met desired standards during traffic pattern. Easy to manage altitude, heading and speed. Met adequate standards for the approach.
2. Describe how aggressive and how precise you could perform the task.	Precise in pattern.
3. Describe predictability of initial aircraft response.	Predictable in traffic pattern. The outcome of power changes was not predictable during the approach. FPV was very sensitive to power changes during the approach.
4. Describe any objectionable oscillations or tendency to overshoot.	No objectionable oscillations or tendency to overshoot in traffic pattern. Had considerable oscillation in yaw at the bottom of the approach.
5. Describe strategy for performing the task.	No particular strategy for traffic pattern. Used FPV to maintain approach angle.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, altimeter, VSI, A/S, horizon line, FPV. Need an angle of bank indicator for turns.

Pilot 1: – Task: Traffic Pattern **Symbology: Compressed**	**Flight Control System: AFCS** **HQR Rating: 4.5 (TP) –** Minor/Moderate deficiencies. Desired/Adequate performance required considerable pilot compensation. **HQR 5 (Approach) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Easier to set pitch attitude in AFCS mode compared with VelStab. Able to meet demand on A/S, heading, and altitude. There were some excursions in altitude and ROC.
2. Describe how aggressive and how precise you could perform the task.	Aggressive and precise. Limited bank angles to 30°. Higher bank angle added workload.
3. Describe predictability of initial aircraft response.	ROC, Altitude capture were predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	Overshot ROC as well has desired heading.
5. Describe strategy for performing the task.	Used LOS indicator and horizon line to assist with maintaining airspeed.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	ROC, altimeter, airspeed, and heading tape.

Pilot 2: – Task: Traffic Pattern Symbology: Compressed	**Flight Control System: AFCS** **HQR Rating: 4 (TP) –** Minor deficiencies. Desired performance required considerable pilot compensation. **HQR 5 (Approach) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Difficult to meet desired/adequate standards without a pitch ladder. It was hard to estimate attitude. The resulted in A/S wondering. Had no idea what approach angle I was using on the steep approach.
2. Describe how aggressive and how precise you could perform the task.	Could not be aggressive. When pitch attitude varied by 1/2° A/S varied by 8 knots which results in chasing altitude.
3. Describe predictability of initial aircraft response.	Pitch attitude, altitude an airspeed were not predictable due to lack or precise pitch symbology.
4. Describe any objectionable oscillations or tendency to overshoot.	A/S oscillations occurred due to a lack of precise attitude cues.
5. Describe strategy for performing the task.	None mentioned.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Pitch ladder would have made this task much easier.

Pilot 3: – Task: Traffic Pattern Symbology: Compressed	**Flight Control System: AFCS** **HQR Rating: 3 (TP) –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance. **HQR 5 (Approach) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Small cyclic inputs needed for pitch control. Easy to maintain speed standard. Switching from rate command to attitude command could present training challenges. Maintaining approach angle was moderately difficult.
2. Describe how aggressive and how precise you could perform the task.	Not aggressive. Shallow bank angles increased precision. Could not be aggressive on approach. Multi-axis task.
3. Describe predictability of initial aircraft response.	Tendency to over control the SAC – light touch required. Tendency to overshoot pitch attitude control. Tendency to PIO in pitch during the approach segment.
4. Describe any objectionable oscillations or tendency to overshoot.	Slight tendency to overshoot heading and altitude but not objectionable.
5. Describe strategy for performing the task.	Used scene content to accelerate. Used 50% TQ to get 500-fpm ROC. Used pitch to manage A/S. Cross checked heading, A/S and VSI. Used the FPV to manage steep approach angle.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	No objectionable symbology. Used heading tape, VSI, altimeter, A/S. FPV was valuable during approach.

Pilot 4: – Task: Traffic Pattern Symbology: Compressed	**Flight Control System: AFCS** **HQR Rating: 4 for both TP and Approach –** Minor deficiencies. Desired performance required considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Was able to meet desired on all parameters for the TP with minor exceptions. Met desired on the approach.
2. Describe how aggressive and how precise you could perform the task.	Required aggressive cyclic input to get to 80 kts. Heading tape was easy to use because the target heading was always visible. Did not have to be aggressive during roll out. It was difficult to maintain the steep and consistent approach angle. Generally precise during the approach until the bottom.
3. Describe predictability of initial aircraft response.	Cyclic and collective coupling was not predictable during approach especially during the deceleration.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency for a transient up and down during deceleration at the bottom of the approach.
5. Describe strategy for performing the task.	Used FPV to maintain constant steep approach angle.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Needed a reliable pitch reference for the approach. The horizon line was not usable during the steep approach.

Pilot 5: – Task: Traffic Pattern Symbology: Compressed	**Flight Control System: AFCS** **HQR Rating: 3 (TP) –** Fair – Some mildly unpleasant deficiencies. Minimal pilot compensation required for desired performance. **HQR 5 (Approach) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Able to meet desired standards for traffic pattern. The approach was a high workload task to attain adequate performance.
2. Describe how aggressive and how precise you could perform the task.	More predictable than in VelStab. No requirement to be aggressive during the traffic pattern. Was not as aggressive as required on approach which resulted in a shallower approach angle.
3. Describe predictability of initial aircraft response.	Easy to predict what the outcome of control inputs 10 seconds in advance during traffic pattern. Liked rate controller because you don't have to hold constant pressure in the SAC.
4. Describe any objectionable oscillations or tendency to overshoot.	Small oscillation in A/S. Tended to over/undershoot by small amounts during traffic pattern. Overshot/undershot approach angle because there were no usable symbology cues. Has difficulty using the FPV effectively.
5. Describe strategy for performing the task.	Think ahead of what attitude and angular rate you desired and put that into the flight controls and then adjust from there after cross check. On approach used a 1000 fpm rate of descent then a moderate deceleration.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Heading tape, altimeter, A/S, VSI. The VSI was very helpful.

Pilot 6: – Task: Traffic Pattern Symbology: Compressed	**Flight Control System: AFCS** **HQR Rating: 8 (TP) –** Major deficiencies. Considerable pilot compensation is required for control. **HQR 5 (Approach) –** Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.
1. Describe your ability to meet "Desired" / "Adequate" performance standards.	Was not able to achieve adequate standards during traffic pattern due mainly to a slow cross check for altitude. High workload during the approach in maintaining approach angle.
2. Describe how aggressive and how precise you could perform the task.	Could not be aggressive. Slowed down the turns due to slow cross check. Could not be aggressive and precise during the approach.
3. Describe predictability of initial aircraft response.	Heading management was predictable. Altitude control was very difficult because of an inability to hold a cruise power setting with collective. Response predictable in cyclic but not collective. Aircraft response was predictable.
4. Describe any objectionable oscillations or tendency to overshoot.	Tendency to overshoot/undershoot approach angle once you lose the FPV. No cues to keep you on the approach angle.
5. Describe strategy for performing the task.	Flew the FPV exclusively once the aircraft was decelerated and in a controllable descent.
6. Describe the symbology used to perform task. Were there objectionable characteristics? Was there symbology needed but not provided?	Used heading tape, VSI, FPV, altimeter. Could not use the horizon line to determine wings level.

APPENDIX B: DATA RUN SHEETS

NOTE: This appendix contains more than 1500 data run sheets. In the interest of conservation, a complete copy of these data are available upon special request. To obtain a copy of the full data set, contact Jay Shively by email at jshively@mail.arc.nasa.gov or call (650) 604-6249.

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14. ABSTRACT

The Aeroflightdynamics Directorate (AMRDEC) conducted a simulation to assess the performance associated with a Contact Analog, world-referenced heading tape as implemented on the Comanche HIDSS when compared with a compressed heading tape similar to that specified by the former MIL-STD-1295. Six experimental test pilots flew three modified ADS-33 maneuvers and a precision traffic pattern in the NASA Vertical Motion Simulator (VMS). Test data showed compressed symbology in the VelStab flight mode produced the lowest mean HQR. All other symbology/flight mode combinations yielded higher HQRs, which characterized opinions that deficiencies in aircraft handling due to HMD symbology would need improvement. Compressed symbology in the VelStab flight mode generally produced the most precise performances over Contact Analog symbology with respect to handling, altitude, position, and time criteria specified for the maneuvers tested. VelStab outperformed AFCS on all maneuvers for both symbol sets. NASA-TLX rated compressed symbology in the VelStab flight mode as the least demanding on resources, closely followed by ratings for Contact Analog in the VelStab mode.

15. SUBJECT TERMS
Helmet mounted display, Flight symbology, Contact Analog symbology

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